ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY
SCHOOL OF GRADUATE STUDIES
DEPARTMENT OF CIVIL ENGINEERING

CHARACTERIZING AND ENGINEERING CLASSIFICATION OF GUGUBA SOILS WHICH IS POTENTIALLY FOUND IN DIRE DAWA, EASTERN ETHIOPIA.

By
Abdi Dereje

"A thesis submitted to the school of graduate studies of Adama Science and Technology University in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering"

Advisor
Argaw Asha (PhD)

August 2017/Adama Ethiopia

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Declaration

This thesis is my original work and has not been presented for a degree in any other university, and that all sources of material used for the thesis have been duly acknowledged.

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Symbols and Abbreviations

Designation	Description
LL	Liquid limit
PL	Plastic limit
PI	Plasticity Index
SL	Shrinkage Limit
γ_w	unit weight of water
G_s	specific gravity
GI	Group Index
PRA	Public Roads Administration
ACS	Airfield Classification System
USCS	unified Soil Classification System
AASHTO	American Association of State Highway and Transportation Officials
DD	Dire Dawa
DDA	Dire Dawa Administration
DDAC	Dire Dawa Administration Council
DDAEPA	Dire Dawa Administration Environmental Protection Authority
ASTM	American Society for Testing and Materials
W	Well graded material;
U	Uniform material;

P	Poorly graded material;
C	Well graded with some clay;

Abstract

Classification of soils, can be used to apply the principle functions of soil science in engineering to predict soil behavior in ordered to use for construction industries or any civil engineering projects. Particle size refers to the grain size distribution of the whole soil and includes stones and gravel as well as sand, silt and clay particles.

Each particle size family is defined by its properties that tend to a group of soils in relation to use and management. [1]***Guguba*** soils found in Dire Dawa are not classified using scientific methods as requirements for any construction application. Therefore, this research is conducted to identify the major groups or classification of the soils and develop standardized materials for construction materials or purposes.

This research was conducted through identifying the potential areas in which ***Guguba*** soils found from map study, walking in all kebeles (site reconnaissance) and laboratory experiments to evaluate the engineering behavior of soil samples collected from eight kebeles of the city.

From the study G***uguba*** soils was fine grained soils with mostly Silt materials. And silty sand soils in which the percentage of clay ranges from 7.26-17.07%, silt from 29.14-50.87%, sand from 37.22-49.80 % and gravel 0-25%. It has similar engineering properties and the same group classification. The soils have free swell value of less than 50% which was non expansive. And compression strength of ***Guguba*** soil ranges from 233.27 Kpa-568.7 kpa and shear strength ranges 116.63 kpa to 284.35 Kpa that showed the soils are very stiff and hard.

Keywords:

[1]**Guguba:** The local name of the soil given by surrounding people found in Dire Dawa city., Dire Dawa, Classification, Malka jabdu, Bargale, Goro, Tony, Gandakore, Sabian, Shinille, Lagahare

CHAPTER 1

1.1 INTRODUCTION

Soil classification is a set of procedures by which a great number of different soil types existing in nature are classified into groups of similar mechanical properties and behaviors in response to the influence of load. Placing a soil that is being tested into a particular predefined group makes it easier for engineers all over the world to study and understand soil test results, and to communicate with one another, and compare results obtained in different laboratories. Classification enables rough identification of the type of material and definition of the range in which its mechanical properties are expected to vary.

Deposits that exhibit, in general, similar average properties can be grouped together, as a class. Classification of soil is essential because, by classifying a soil, a fairly accurate idea of its average properties, can be made. An estimation of these average properties by classification is helpful in ordinary soil engineering projects. The opinion, however on the applicability of classification of soils differs among soil engineers. The difference of opinion arises mainly due to the fact that many classification systems exist. Some systems take into consideration only the grain-sizes of the soils, while other take into consideration the plastic properties, while quite another classification exists, which defines soils in terms of their origin and general features.

So, a soil classified into a group of different system may fall into quite another group of system. Also in the same system there is a possibility that a soil may form a borderline, in which, it could be classified under two groups.

Classification of a soil is a mere indicator to its general properties and behavior of a soil cannot be solely predicted from its classification alone.

Dire Dawa City is one of the fastest growing cities in the country and there is a big volume of construction works. Since it is the transit way on the road from Ethiopia to Djibouti, the growth of trade and commerce is very high in the city. Due to its location and near distance which is around 313km from Djibouti investors are attracted to construct in Dire Dawa City and the nearby areas. And the people who are living in the city with having low income are using guguba soils to construct their home, fence and the like. The use of the engineering property of this soil existed in the city is not studied. This research is therefore directed to the study of the engineering classification of the soils in order to improve for further use of this soils.

1.2. Objectives

1.2.1 General Objectives

To determine of the engineering classification of guguba soil existed at Dire Dawa city.

1.2.2 Specific Objectives

- To determine this soil classification as per AASHTO classification system and Unified Soil classification methods.
- To identify whether this soils have good shearing strength or not for further geotechnical engineering projects.
- To identify the response of the soil under a given load and condition by using compaction and free swell tests.
- To evaluate the soils specific gravity to identify the soils are suitable for the production of the cement or not.

1.3. Scope of the Study

Eight samples of soil from the city were collected. The scope of this study is limited to investigating the index properties and engineering characteristic of the guguba soil. Due to the budget constraint, the investigation in this research is limited to the eight kebeles of the city.

1.4. Structure of the Thesis

This thesis work is divided in to five Chapters, each covering a specific topic of the research work. In this introductory Chapter the background of the problem, objective, and scope of the thesis work and structure of the thesis are presented. Chapter two deals with a brief literature review. Chapter three deals with the description of study area and experimental techniques in which this research is done. And also, sample collection methods were stated. The fourth chapter deals with sample description and the types of laboratory tests conducted and results obtained. The discussion on the laboratory results obtained from this work has been covered in this chapter too. The fifthy chapter deals with Conclusion and recommendations drawn from the research. Finally, soil data profile of kebeles, laboratory results and rain fall data are included in appendix

CHAPTER 2

2.1 LITERATURE REVIEW

2.1.1 General

Soil classification is a set of procedures by which a great number of different soil types existing in nature are classified into groups of similar mechanical properties and behaviors in response to the influence of load. Placing a soil that is being tested into a particular predefined group makes it easier for engineers all over the world to study and understand soil test results, and to communicate with one another, and compare results obtained in different laboratories. Classification enables rough identification of the type of material, and definition of the range in which its mechanical properties are expected to vary.

Initial efforts to classify soil for engineering applications are strictly related to the classification according to the size of grains, i.e. according to the grain size composition of soil [1]. Such systems were based on soil texture i.e. on relative proportions of sand, silt and clay in the total mass of soil tested. Texture-based classifications of soil were first investigated in detail by Atterberg in the early 20th century [2, 3].

The best known classification based on texture is the classification developed by the USDA (US Department of Agriculture) in 1938. This classification was modified on several occasions since its initial appearance [4]. It is based on the use of a triangular classification diagram [5]. This classification is nowadays more used in agriculture than in geotechnical engineering. Atterberg pointed out in his papers that textural classifications of soil can successfully be used in agriculture, but that some other clay and silt parameters must also be considered when this classification is used in geotechnical applications.

Arthur Casagrande developed the ACS classification (Airfield Classification System) for the design of the US airfields during the Second World War [6]. This classification is based on the grain size distribution and consistence of coherent soil particles. The modification of the ACS classification resulted in 1952 in the creation of the USCS (unified Soil Classification System) soil classification, which is an integral part of the US standards ASTM D 2487-11. [7]

USCS system was firstly developed by Arthur Casagrand for wartime airfields construction in 1942 and the system was modified and adopted for regular use by Army Corps of Engineers and then by the Bureau of Reclamation in 1952 as the Unified Soil Classification System. Currently ASTM (D-2487) adopts it. [7]

The System uses six major symbols and modifiers as in the following

- Major Symbols

G	Gravel
S	Sand
M	Silt
C	Clay
O	Organic
Pt	Peat

- Modifiers

W	Well graded (for gravel and sand)
P	Poorly graded (for gravel and sand)
H	High plasticity (for silt, clay, and organic soils)
L	Low plasticity (for silt, clay, and organic soils [7]

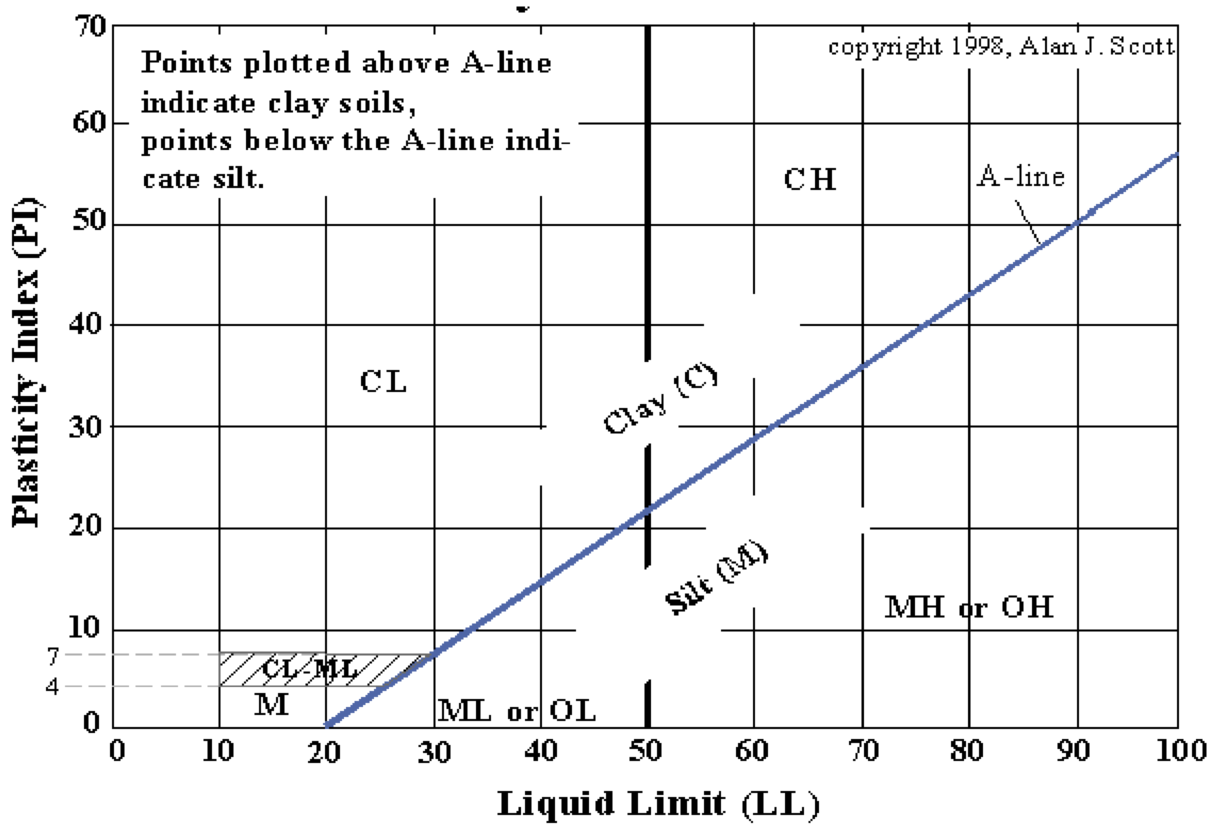

Figure.2.1 Plasticity chart flow [8,9]

2.1.2 AASHTO Classification System

The U.S Bureau of Public Roads (now the Federal Highway Administration) developed AASHTO soil classification in the late 1920s for road construction. The current version, which was revised in 1945, is used for extended applications in road bases AASHTO Method M 145). The revised system comprises seven groups of inorganic soils, A-l to A-7 with 12 subgroups in all. The system is based on the following three soil properties. [10]

2.1.3 Procedure for grain size determination

Different procedures are required for fine and coarse-grained material. Detailed procedures are described in the Australian Standard AS 1289.A1, Methods of testing soil for engineering purposes. These will be demonstrated in a laboratory session.

- Coarse

Sieve analysis is used to determine the distribution of the larger grain sizes. The soil is passed through a series of sieves with the mesh size reducing progressively, and the proportions by weight of the soil retained on each sieve are measured. There are a range of sieve sizes that can be used, and the finest is usually a 75 μm sieve. Sieving can be performed either wet or dry. Because of the tendency for fine particles to clump together, wet sieving is often required with fine-grained soils. [11]

- Fine

To determine the grain size distribution of material passing the 75μm sieve the hydrometer method is commonly used. The soil is mixed with water and a dispersing agent, stirred vigorously, and allowed to settle to the bottom of a measuring cylinder. As the soil particles settle out of suspension the specific gravity of the mixture reduces. A hydrometer is used to record the variation of specific gravity with time.

By making use of Stoke's Law, which relates the velocity of a free falling sphere to its diameter, the test data is reduced to provide particle diameters and the % by weight of the sample finer than a particular particle size. [11]

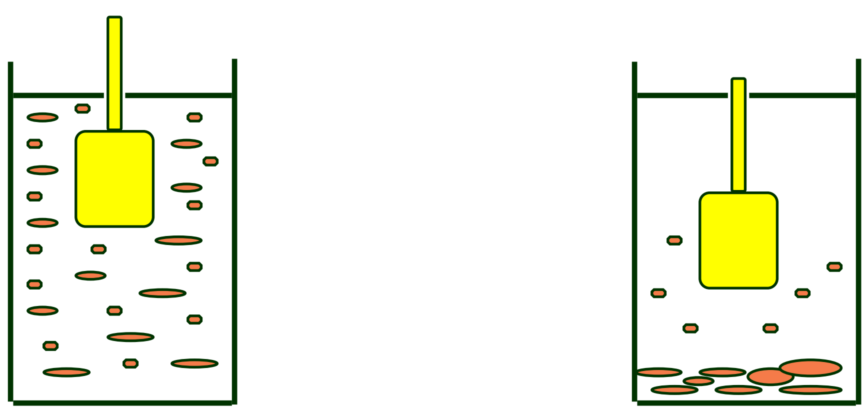

Figure 2.2 A schematic view of the hydrometer test [11]

2.1.4 Grading curves

The results from the particle size determination tests are plotted as grading curves. These show the particle size plotted against the percentage of the sample by weight that is finer than that size. The results are presented on a semi-logarithmic plot as shown in Figure below. The shape and position of the grading curve are used to identify some characteristics of the soil.[12]

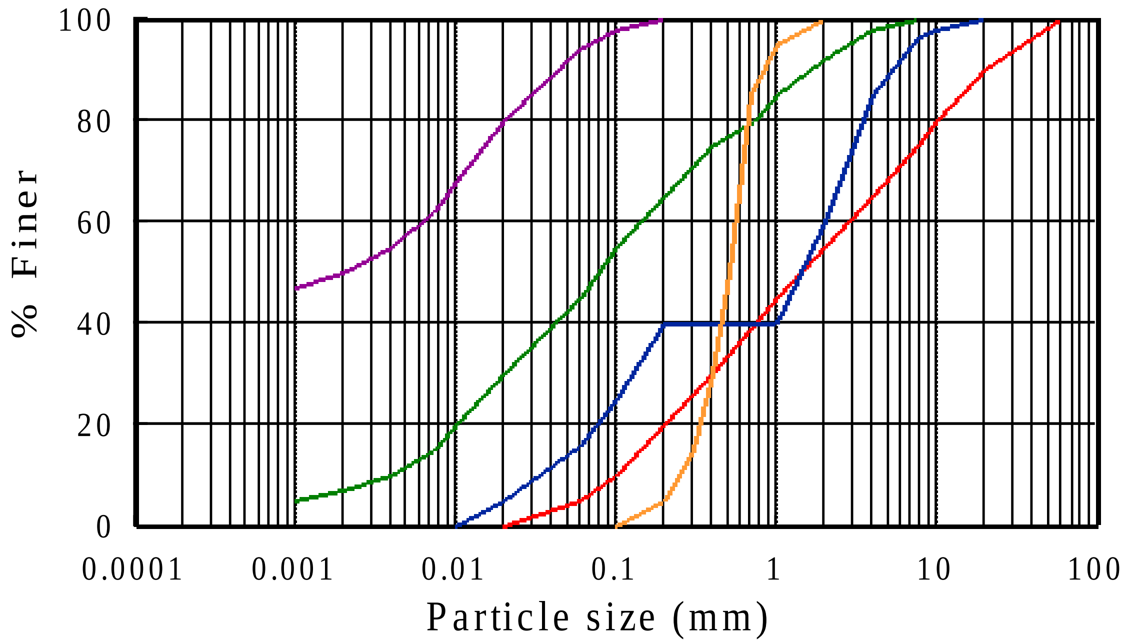

Figure 2.3 Typical grading curves **[12]**

Some typical grading curves are shown on the figure. The following descriptions are applied to these curves

W Well graded material

U Uniform material

P Poorly graded material

C Well graded with some clay

F Well graded with an excess of fines

The use of names to describe typical grading curve shapes and positions has developed as the suitability of different grading for different purposes has become apparent. [13]

From the typical grading curves, it can be seen that soils are rarely all sand or all clay, and in general will contain particles with a wide range of sizes. Many organizations have produced charts to classify soils giving names for the various combinations of particle sizes.

2.1.5 Atterberg Limits

These tests are only used for the fine-grained, silt and clay, fraction of a soil (actually the % passing a 425 μm sieve). If we take a very soft (high moisture content) clay specimen and allow it to dry. As the soil dries its strength and stiffness will increase. Three limits are indicated, the definitions of which are given below. The liquid and plastic limits appear to be fairly arbitrary, but recent research has suggested they are related to the strength of the soil. [14]

The Atterberg Limits and relationships derived from them are simple measures of the water absorbing ability of soils containing clay minerals. For example, if a clay has a very high LI and LL it is capable of absorbing large amounts of water, and for instance would be unsuitable for the base of a pavement. The LL and PL are also related to the soil strength.[15]

Only the fraction finer than 425 μm is tested in the Atterberg Tests. If this fraction is only small (that is, the soil contains significant amounts of sand or gravel) it might be expected that the soil would have better properties. While this is true to some extent it is important to realize that the soil behavior is controlled by the finest 10 - 25 % of the particles. [15]

A Group Index is introduced to further differentiate soils containing appreciable fine-grained materials. The characteristics of various groups are defined in table 2.1.

Table 2.1 AASHTO soil classification system[14]

General Classification	Granular Materials (35% or less passing No. 200 sieve)							Silt-Clay Materials (More than 35% passing No. 200 sieve)			
Group Classification	A-1			A-2							A-7
	A-1-a	A-1-b	A-3	A-2-4	A-2-5	A-2-6	A-2-7	A-4	A-5	A-6	A-7-5 A-7-6
Sieve Analysis, Percent passing:											
No. 10 (2.00 mm)	50 max.	....	....	....	....	....	....	....	....	....	....
No. 40 (0.425 mm)	30 max.	50 max.	51 min.	....	....	....	....	....	....	....	....
No. 200 (0.075 mm)	15 max.	25 max.	10 max.	35 max.	35 max.	35 max.	35 max.	36 min.	36 min.	36 min.	36 min.
Characteristics of Fraction Passing No. 40 (0.425 mm)											
Liquid limit	....		....	40 max.	41 min.	40 max.	41 min.	40 max.	41 min.	40 max.	41 min.
Plasticity index	6 max.		N.P.	10 max.	10 max.	11 min.	11 min.	10 max.	10 max.	11 min.	11 min.
Usual Types of Significant Constituent Materials	Stone Fragments, Gravel and Sand		Fine Sand	Silty or Clayey Gravel and Sand				Silty Soils		Clayey Soils	
General Ratings as Subgrade	Excellent to Good							Fair to Poor			

The placing of A-3 before A-2 is necessary in the "left to right elimination process" and does not indicate superiority of A-3 over A-2.

Plasticity index of A-7-5 subgroup is equal to or less than LL minus 30. Plasticity index of A-7-6 subgroup is greater than LL minus 30.

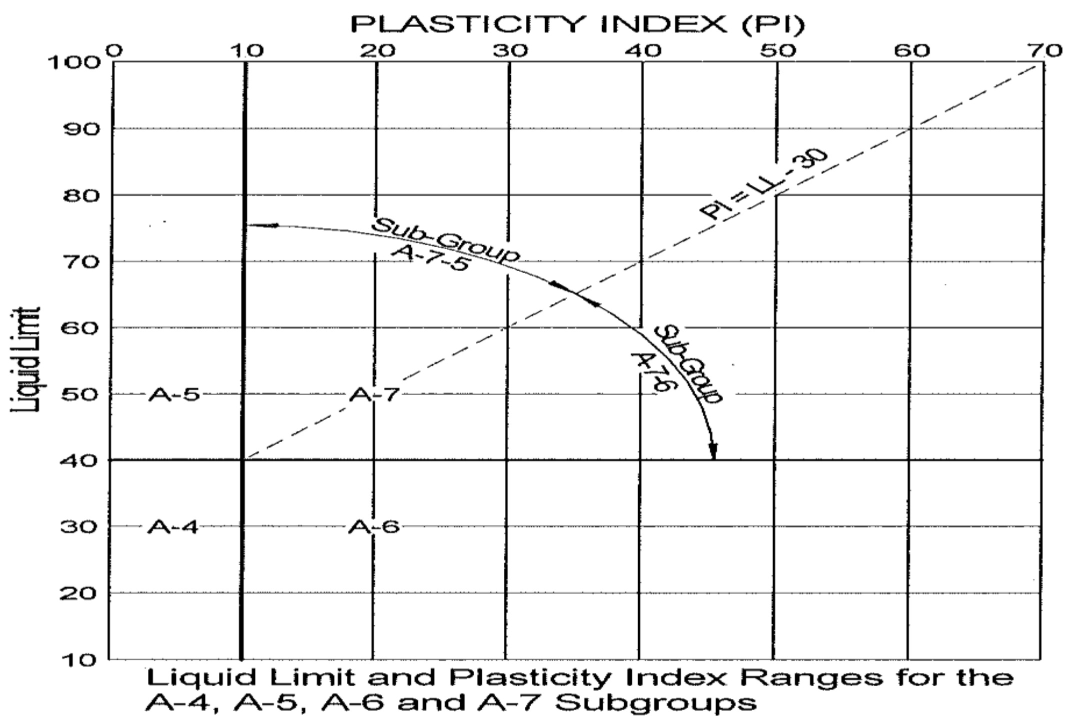

Figure 2.4 Chart for use in AASHTO soil classification system [14,15]

2.1.6 Classification Methodology

With the required data in mind, proceed from left to right in the chart. The correct group will be found by a process of elimination. The first group from the left consistent with the test data is the correct classification.

The A-7 group is subdivided into A-7-5 or A-l-6 depending on the plasticity index,

For A-7-5, lp < w / - 30 ----------------Equation (2.7)

ForA-7-6, 7 p > w / - 3 0 ----------------Equation (2.8)

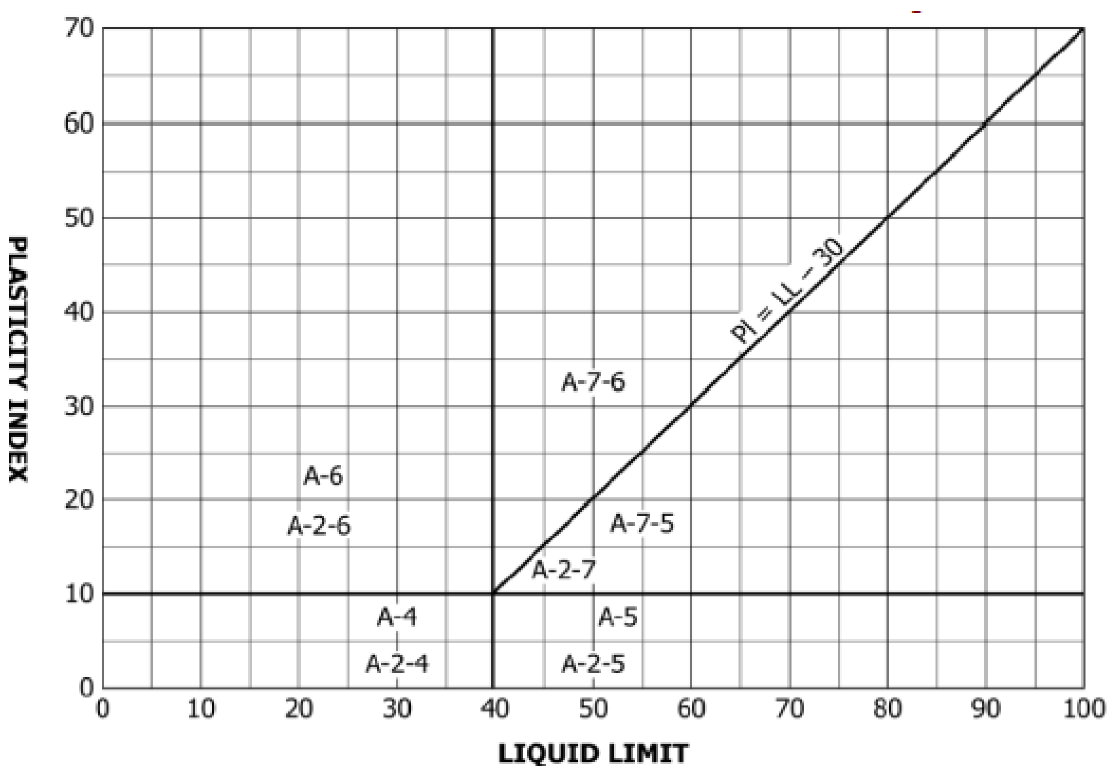

Figure 2.5 Chart for use in AASHTO soil classification system [16]

2.1.7 Compaction Test

Mechanical compaction is one of the most common and cost effective means of stabilizing soils. During compaction air is expelled from the void spaces. Thus compaction results in an increase in the density of the soil. An extremely important task of geotechnical engineers is the performance and analysis of field control tests to assure that compacted fills are meeting the prescribed design specifications. Design specifications usually state the required and the water content. In general, most engineering properties, such as the strength, stiffness, resistance to shrinkage, and imperviousness of the soil, will improve by increasing the soil density [17].

Results are used to determine appropriate methods of field compaction and to provide a standard by which to judge the acceptability of field compaction [18].

The optimum water content is the water content that results in the greatest density for a specified compactive effort. Compacting at water contents higher than (wet of) the optimum water content results in a relatively dispersed soil structure (parallel particle orientations) that is weaker, more ductile, less pervious, softer, more susceptible to shrinking, and less susceptible to swelling than soil compacted dry of optimum to the same density. The soil compacted lower than (dry of) the optimum water content typically results in a flocculated soil structure (random particle orientations) that has the opposite characteristics of the soil compacted wet of the optimum water content to the same density [19].

Two types of compaction tests routinely performed are: (1) The Standard Proctor Test, and (2) The Modified Proctor Test. In the Standard Proctor Test, the soil is compacted by a 24.4N hammer falling a distance of 0.305meters into a soil filled mold. The mold is filled with three equal layers of soil, and each layer is subjected to 25 drops of the hammer. The Modified Proctor Test is identical to the Standard Proctor Test, except it employs, a 44.5N hammer falling a distance of 0.457meters, and uses five equal layers of soil instead of three. There are two types of compaction molds used for testing. The smaller type is 0.102meters in diameter and has a volume of about 944 cm3, and the larger type is 0.152meters in diameter and has a volume of about 2123 cm3. If the larger mold is used each soil layer must receive 56 blows instead of 25[19].

2.1.8 Free swell

Both the amount of swelling and the magnitude of swelling pressure are known to be dependent on the clay minerals, the soil mineralogy and structure, fabric and several physico-chemical aspects of the soil. Among clay minerals Montimorillonite influence the magnitude of swelling maximally as compared to Illites and Kaolinites [19].

To study the swelling property of the soils, the simplest test conducted is free swell test. This test is performed by slowly pouring 10ml of oven dry soil which has passed the No.40 (0.425mm) sieve in to 100 ml graduated cylinder filled with distilled (tap) water. After 24 hours, final volume of the suspension being read. Hence, free swell is defined as:

$$\text{Free swell} = \frac{\text{Final volume} - \text{Initial volume of the soil}}{\text{Initial volume}} \times 100\% \qquad (2.9) \quad [20]$$

2.1.9 Specific gravity

Specific gravity is the ratio of the mass of unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature. The specific gravity of a soil is used in the phase relationship of air, water, and solids in a given volume of the soil [20].

The specific gravity of the minerals affects the specific gravity of soils derived from them. The specific gravity of most rock and soil forming minerals varies from 2.50 (some Feldspars) and 2.65 (Quartz) to 3.5 (Augite or Olivine). Gypsum has a smaller value of 2.3 and salt (NaCl) has 2.1. Some iron minerals may have higher values, for instance, magnetite has 5.2[18, 21].

According to ASTM D 854-98, two procedures for performing specific gravity are provided. These are Method-A, procedures for oven dried specimen and Method-B, procedure for moist specimen. For specimens of organic soils and highly plastic, fine grained soils, Procedure B shall be the preferred method.

CHAPTER 3

3.1 DESCRIPTION OF STUDY AREA AND EXPERIMENTAL TECHNIQUES

3.1.1 Area of Study

Proclamation No.416/2004 provides Dire Dawa the legal status that enables it to become a chartered city, the residents of the Dire Dawa Administration have, therefore, the legal foundation that enables to exercise self-administration.This proclamation makes it imperative that the entire wellbeing of the residents be ensured, and that efficient and cost-effective municipal service be equitably provided/ delivered so as to make it a modern and competitive work and residential city in which the entire well-being of its residents is ensured.

3.1.1.2 General Feature

3.1.1.3 Geographical Location

The Dire Dawa Administrative Region is located in the eastern part of Ethiopia. The region is bordered by the Shinile Zone of the Somali National Regional State on the northwest, northeast, and by the eastern Hararghie Region of the Oromia National Regional State on the south, southeast, and east.

The region is estimated to have a total land area of 128,802 hectares of land, of which 97.73% covers the rural area, and the remaining 2.27% accounts for the land area used by the region's main urban centre: Dire Dawa city, located 515 km from Addis Ababa, 49 km from Harar, and 313 km from Port Djibouti.

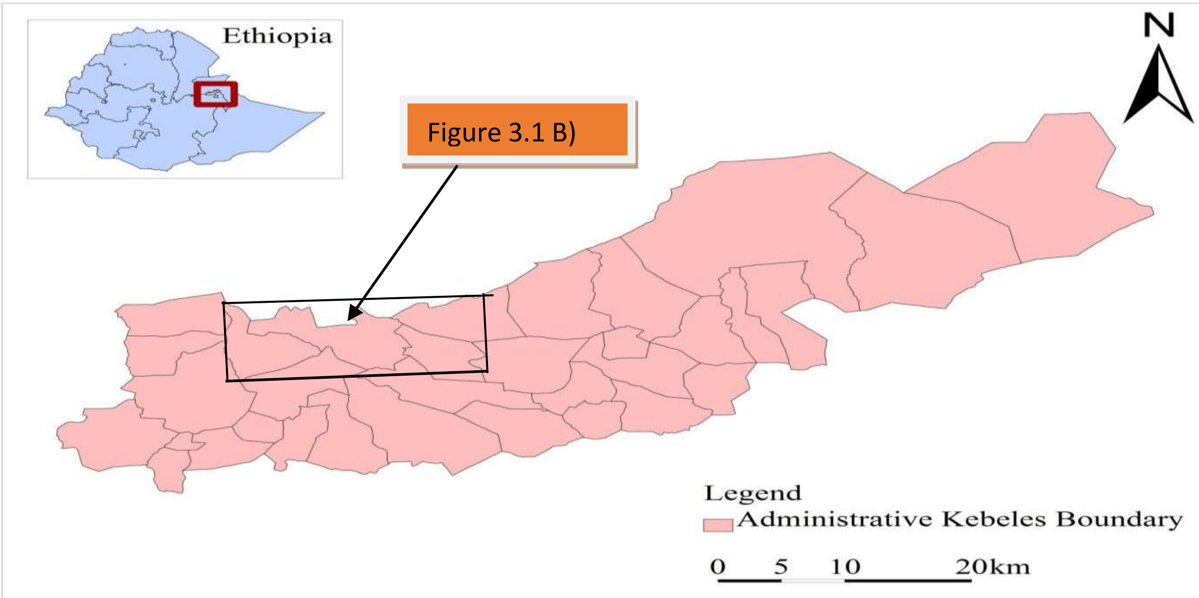

Figure 3.1 A) Location and map of Dire Dawa Administration.

Table 3.1 Global Coordinates of Sampling Area

Designation	Location	X-Direction	Y-Direction
Tmj	Malka Jabdu Area	0805759	1064060
Tbr	Bargale Area	0811314	1061894
Tgr	Goro Area	0811882	1061472
Ttn	Tony Area	0811745	1063997
Tgk	Ganda Kore Area	0813259	1061166
Tsb	Sabian Area	0812485	1063137
Tsh	Shinille Area	0815128	1063996
Tlh	Laga Hare Area	0816159	1061991

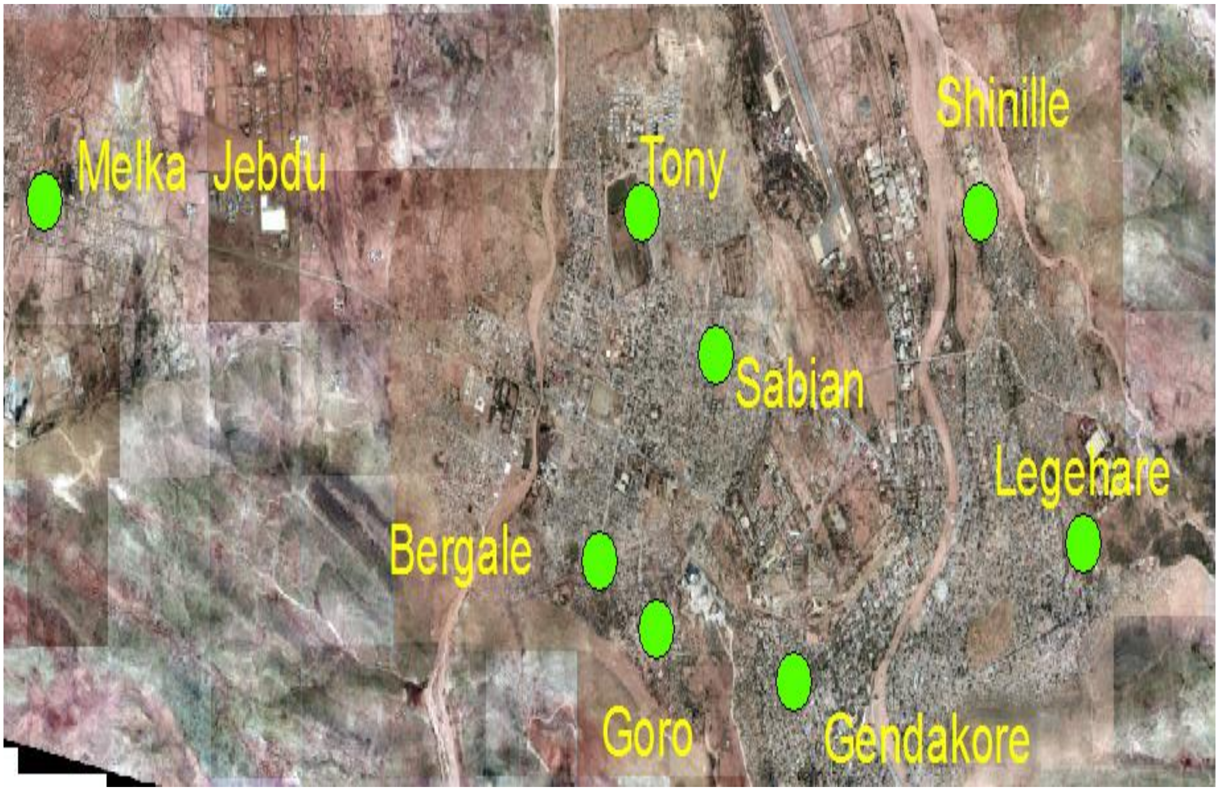

Figure 3.1 B) Location of sampling areas shown on map of Dire Dawa City Administration

As was reported by DDAEPA (2011) and observed during this study, the general landscape of the Administration can be categorized into four physiographic units as: (a) mountain ranges with slopes that exceed 45%, (b) isolated hills found scattered all over the Administration, with slopes ranging between 16 and 30%, with very shallow soils composed mainly of stones and rock. (c) valley bottoms and river terraces mainly situated at the foot of mountain ranges, hills, and seasonal river banks with moderately deep soils and with slopes that range from 0 to 3%; and (d) flat plains mostly concentrated in the northeastern and northwestern parts, with slopes ranging between 0 and 3%,

3.1.1.4 Climate

The climatic condition of the region seems to be greatly influenced by its topography, which lies between 950-2450 MASL, and which in the main is, therefore, characterized by warm and dry climate with a relatively low level of precipitation. The mean annual temperature of the region is about 25.4^{0}C. The average maximum temperature of the region is 31.4^{0}C, while its average minimum temperature is about 18.2 ^{0}C.

The region has two rain seasons; that is, a small rain season from March to April, and a big rain season that extends from August to September. The aggregate average annual rainfall that the region gets from these two seasons is about 604 mm. On the other hand, the region is believed to have an abundant underground water resource.

3.1.1.5. Number of Population

The number of population of the region is at present estimated to be about 342,827 of which 67.9% reside in urban area and the rest 32.1% lives in rural areas. Being one of the largest urban centers in the country, Dire Dawa has become home for peoples from a number of nations and nationalities found in the country as well as for people from India, Yemen, and Turkey etc.

3.1.1.6. Languages and Religions

A number of Ethiopian Languages including Amharic, Oromiffa, Somali, Guragigna, Tigrigna, and Harari, etc. are widely spoken in Dire Dawa. Amharic is used as a working language in the city.

The predominant religions practiced in the region are Islam and Christianity. However, we can find people from other religious groups like Hindu and the like in the city.

3.1.2 Experimental Technique and Methodology

3.2.1 Methodology's

3.1.2.1 Map Study (office work)

On the basis of the identified diagnostic horizons, diagnostic properties, and materials, six Reference Soil Groups (RSGs) and 19 soil mapping units were identified. The six RSGs are Leptosols, Calcisols, Luvisols, Cambisols, Arenosols, and Regosols. In general, the Leptosols occur on the steep slopes, while the other soil groups occupy the gently undulating lands, plains and the valleys. In terms of area coverage, the Leptosols, Calcisols, Luvisols, Cambisols, Arenosols, and Regosols occupy 29.24, 18.49, 38.71, 4.73, 0.62, and 8.21%, respectively, of the total area of the rural *kebeles*. In terms of area this is equaivalent to 44015.33, 27,830.73, 58,269.87, 7115.54, 933.65, and 12,352.89 ha.

3.1.2.2 SITE VISITING

The site visited indicate the occurrence of different major soil types (as discussed above) in the Administration. This difference in soil types is the result of differences in topography, geology, vegetation, climate, and in some instances, anthropogenic activities.

The general trend observed in the Administration is that, soils formed from calcareous materials, such as lime stones, and fine-textured rocks (e.g, basalt) are generally fine in their texture.

On the other hand, those soils formed from parent materials rich in silica (quartz) are generally coarse in their texture. Topography affects the depth of the soils significantly. In general, soils on the gentle slopes, plains, and valley bottoms are deeper, while those on the steep slopes are generally shallow. There are also areas with no soil-only hard rock.

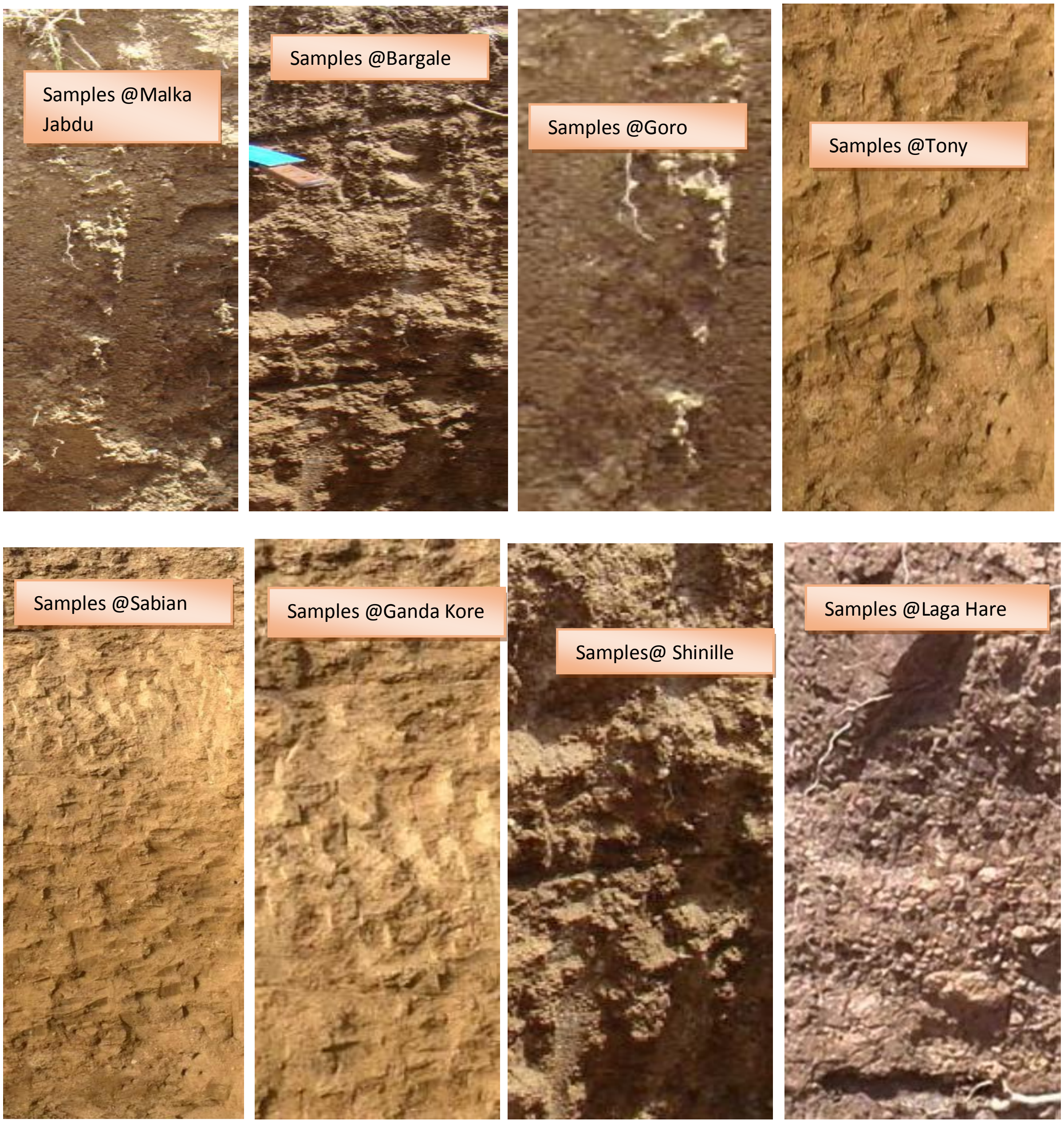

Figure 3.2 Some of the major soil types occurring in kebeles Dire Dawa Administration

3.1.2.3 Laboratory Activities

Laboratory activities were carried out after samples collected from different rural kebeles existed in the Dire Dawa administration city.

Then, from the samples collected the following laboratory tests were done.

- Specific gravity test
- Atterberg limit tests
  - ✓ Liquid limit
  - ✓ Plastic limit
  - ✓ Plastic Index
- Grain size analysis
  - ✓ Sieve analysis (wet method)
  - ✓ Hydrometer
- Free swell test
- Standard compaction test
- Unconfined Compressive Strength Test

All the above tests were done according to American Society for Testing Materials (ASTM) standard

3.1.2.4 Apparatus

To determine engineering soil classification of any type of soils various kind of machines are available. These include sieve, case grand, ultrasonic pulse, piezoelectric bender element, cyclic simple shear and cyclic torsional shear apparatuses [16]. Among these machines cyclic direct simple shear is used for this research.

Figure. 3.3 Case grands Machine

Sieve Analysis: Used to analyze the particle size of soil in order to differentiate accordingly.

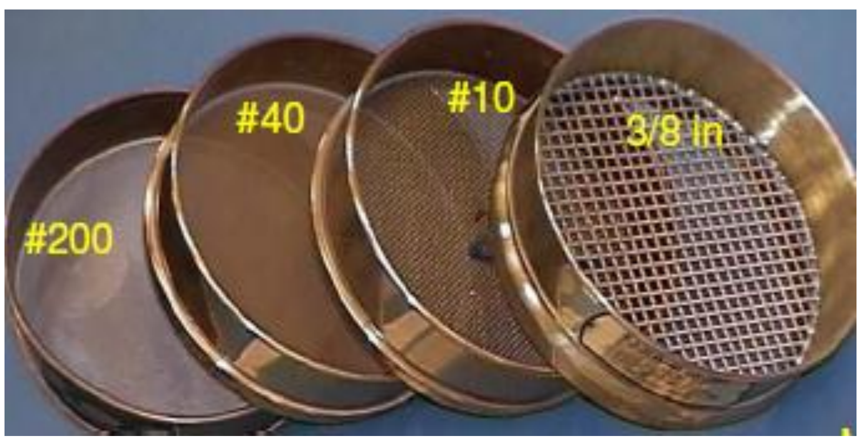

Figure.3.4 Sieve Analysis machine

3.1.2.5 Soil Group Index Classification Methodology as per AASHTO

1. Determine the % of soil passing through #200 sieve (F200). If F200 is more than 35% soil is fine grained otherwise coarse grained.
2. For coarse grained soil:
    a. Determine F10, F40, F200, LL, and PI.
    b. Match the soil group based on the AASHTO Classification.
3. For fine grained soil:
    a. Determine LL, and PI.
    b. Group soil according to the AASHTO classification.
4. Determine Group Index (GI) of the soil as:

$$\text{Group Index : } GI = (F-35)(0.2+0.005(LL-40)) + 0.01(F-15)(PI-10)$$

5. Express GI in whole number.
6. Express the classification first by soil classification and then GI in parenthesis. [14,15]

CHAPTER FOUR

4.1 TEST RESULTS AND DISCUSSION OF TEST RESULTS

4.1.1 SAMPLING, SAMPLE PREPARATION & DESCRIPTION

Guguba soil was type of soil that found in Eastern Ethiopia, Dire Dawa dispesely in different kebeles. Due to financial limitations and time constraints soil samples are taken from eight sites located at different kebeles.

After the base map was produced, the field work was started. The field work involved two major tasks; field auger and pit descriptions. To locate the representative auguring points, an exploratory survey was conducted by walking through accessible parts of every land in the selected kebeles.

Using the base map and the extensive walking in the respective kebeles, augering points were decided and auger pits opened. During the walking, features such as road cuts, gully cuts, exposed rock outcrops, surface texture and soil color were used to observe soil type differences. Appropriate numbers of auger points per kebele were opened to a depth of 3m unless restricted by hard rock or impenetrable layer. Accordingly, a total of 8 auger pits and 8 auger observation points were opened across the eight kebeles of the Administration.

At least 5kg soil samples were collected for laboratory analysis. The samples were properly labelled and transported to Haramaya University for further preparation and analysis.

A total of 8 samples were submitted to the Haramaya University Civil Engineering Department Laboratories. Standard laboratory procedures being used at Haramaya University Soil laboratories were followed in the analysis of the selected soil properties. The soil properties analyzed include particle size distribution, Liquid limit, plastic limit and plastic index.

4.1.1.1 Natural Water Contents and Insitu Density

Since it was difficult to bring undisturbed samples to the laboratory, this test was done by taking moisture can and balance to the field. In the site the weight of the moisture can and the weight of can with moist soil was measured. Then the sample was brought to the laboratory and put it in to drying oven at a temperature of 105+5°c for 24 hours. Then, the natural moisture content was determined. This test was done according to the Standard Reference: ASTM D 2937-00 – Standard. Test for Density of Soil in Place by the Drive-Cylinder Method. The in situ density of the samples around three meter is shown in Table 4.1. Field densities were taken only around three meters because these values were required for remolding sample.

Table 4.1 The In-situ density and natural moisture contents of soil samples

Test Pits	Depth(m)	Natural Moisture content	Insitu Density (g/cm3)	Dry Density (g/cm3)
Tmj	0-1.0	12.21	-	-
	1.0-3.0	23.4	1.42	1.19
Tbg	0-0.8	13.9	-	-
	0.8-3.0	24.14	1.36	1.14
TGr	0.5-1.2	26.03	-	-
	1.2-3.0	29.82	1.22	1.0
Ttn	0.0-0.5	21.11	-	-
	0.5-3.0	21.86	1.26	1.0
Tgk	0.0-1.5	14	-	-
	1.5-3.0	25.1	1.18	1.05
Tsb	0.60-1.5	16.4	-	-
	1.5-3.0	22.09	1.38	1.14
Tsh	0.7-1.8	10.01	-	-
	1.8-3.0	16.46	1.27	1.02
Tlh	0.0-1.5	13.69	-	-
	1.5-3.0	20.28	1.38	1.15

4.1.1.2 Specific Gravity

The specific gravities are determined using both method A and B, as per ASTM D 854-98 procedures. The test results are shown in Table 4.2. From this table we observe that Method-B give more reasonable value than that of Method-A, and values determined on Method-B are used in other calculations like hydrometer analysis. Within the depth of exploration, a specific gravity becomes between 2.30 to 2.65. Therefore, the specific gravity of the soils ranges from 2.30 to 2.65.

Table 4.2 Specific Gravity of guguba Soil

Serial No.	Designation	Specific Gravity at Depth 1.5m-3m		Water used for testing
		Method A	Method B	
1	Tmj	2.48	2.48	Tap water
2	Tbr	2.55	2.65	Tap water
3	Tgr	2.53	2.51	Tap water
4	Ttn	2.36	2.30	Tap water
5	Tgk	2.61	2.65	Tap water
6	Tsb	2.49	2.50	Tap water
7	Tsh	2.47	2.54	Tap water
8	Tlh	2.56	2.55	Tap water

4.1.2 Grain Size Analysis

For a basic understanding of the nature of soil, the distribution of the grain size present in a given soil mass must be known. The distribution of different grain sizes affects the engineering properties of soil. Grain size analysis provides the grain size distribution required in classifying the soil. Grain size Analysis test is used to determine the percentage of different grain sizes contained within a soil.

4.1.2.1 Sieve Analysis Laboratory Results for Malka Jabdu and Bargale site

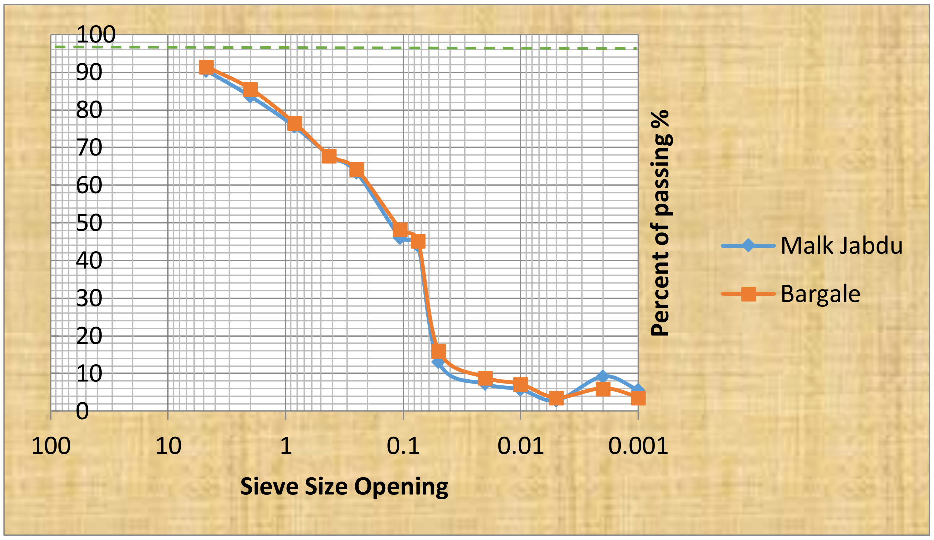

Figure 4.1 Grain size distribution curve for Malka Jabdu and Bargale Site

4.1.2.2 Sieve Analysis Laboratory Results for Goro and Tony site

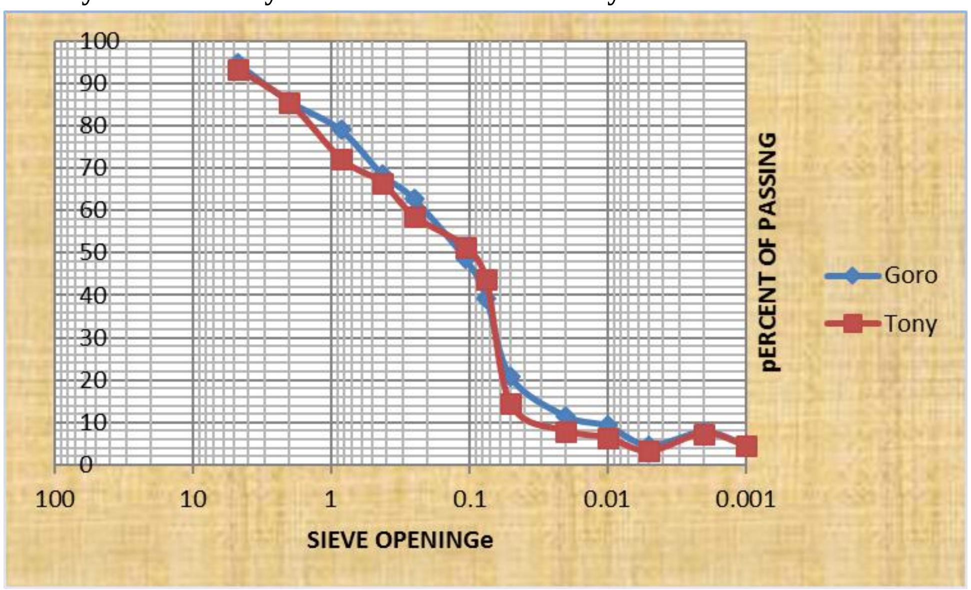

Figure 4.2 Grain size distribution curve for Goro and Tony Site

4.1.2.3 Sieve Analysis Laboratory Results for Malka Jabdu and Bargale site

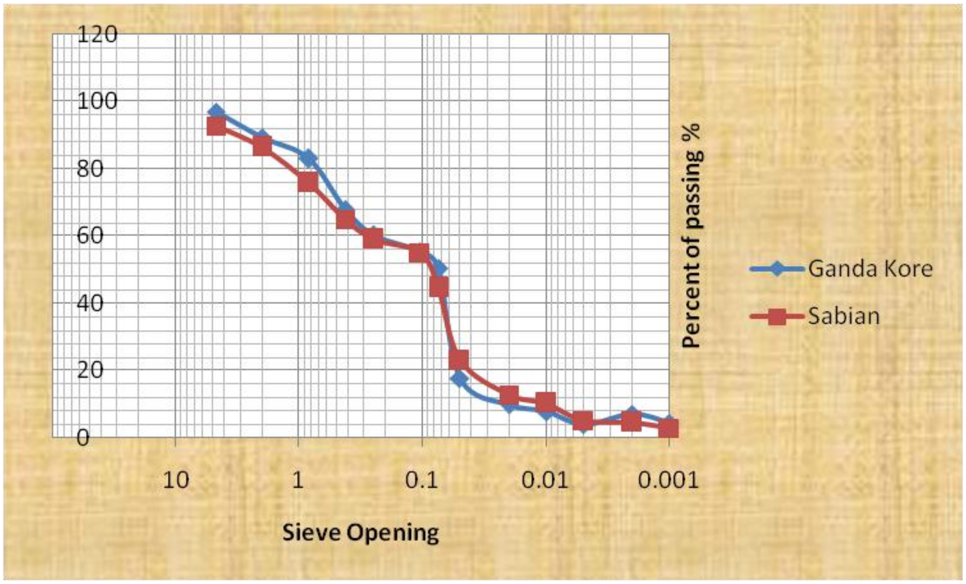

Figure 4.3 Grain size distribution curve for Ganda Kore and Sabian Site

4.1.2.4 Sieve Analysis Laboratory Results for Malka Jabdu and Bargale site

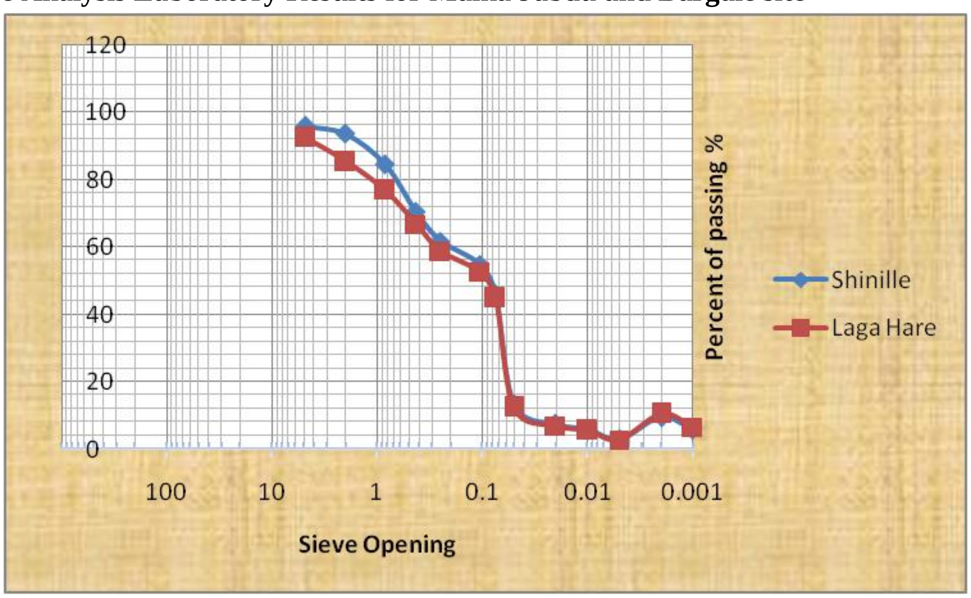

Figure 4.4 Grain size distribution curve for Shinille and Laga Hare Site

From all samples grain size distribution, the percent gravel, sand, silty and clay soil existed can be drawn as the following table 4.3.

Table 4.3 Percent of Gravel, Sand, Silt and Clay existed in all Samples

serial No	Designation	Percent amount of particle size %			
		Gravel	Sand	silt	Clay
1	Tmj	9.52	46.33	29.14	15.01
2	Tbr	8.51	46.15	35.61	9.73
3	Tgr	5.33	36.04	46.08	12.55
4	Ttn	6.706	49.61	31.81	11.88
5	Tgk	3.10	46.53	39.09	11.28
6	Tsb	7.27	37.72	50.87	7.26
7	Tsh	4.15	49.80	29.57	15.33
8	Tlh	7.65	47.45	27.83	17.07

4.1.3 INDEX PROPERTY ANALYSIS

4.1.3.1 Atterberg Limit Analysis

The study results have shown that consistent and repeatable plasticity related index test measurements can be obtained on the soils provided care is taken in their preparation or prior to testing. Therefore, plasticity tests are carried out on soils prepared from their natural or as received water contents. The index properties of soils investigated in this study include natural moisture content, Atterberg limits (liquid and plastic limits, plasticity index).

Data Collected from Malka Jabdu.

The sample collected from Malka Jabdu for determination of group index of the soil was computed as below tables and developed graph.

Table 4.4 (a)Laboratory Observation of Samples for Malka Jabdu Site

s.no	Observations	Observations Liquid Limit			Observations Plastic Limit	
		1	2	3	1	2
1	Number of blows	35	24	15		
2	Mass of empty can(M1)	8.32	8.42	8.33	8.22	8.19
3	Mass of can + wet soil (m2)	21.74	21.18	24.15	14.72	14.07
4	Mass of can + dry soil (m3)	17.70	17.27	19.23	13.28	12.76

Determination of natural moisture content of soils was carried out in this study by oven drying method and this testing procedure specifies a standard drying temperature of 105-110 °C. Soil samples used for natural moisture content determination had been previously collected from the field, where upon they were immediately well sealed in polythene bags to prevent moisture loss.

The moisture content so determined also represents the moisture content of natural undisturbed soil in situ.

Natural moisture content, Wn, of a soil is usually expressed as a percentage of its dry mass and is given by the equation natural moisture content = (loss of moisture/dry mass) * 100%,

or

Wn (%) = ((m2-m3)/(m3-m1)) * 100

where

m1 = mass of empty container

m2 = mass of container + wet soil

m3 = mass of container + dry soil

In this study, up to three separate moisture content determinations were performed on each soil sample. Results of natural moisture content determination of soils performed in this study are presented in table 4.4b below.

Table 4.4 (B) Laboratory Determination for plastic limit for Malka Jabdu Site

s.no	Calculation	Determination LL			Determination PL	
		1	2	3	1	2
1	Mass of water =M2-M3	4.04	3.91	4.92	1.44	1.31
2	Mass of dry Soil =M3-M1	9.38	8.85	10.9	5.06	4.57
3	Water content = (M2-M3)/(M3-M1)	43.07	44.18	45.13	28.46	28.66
Plastic Limit P+L					= (28.46+28.66)/2=28.56	

From table 4.4(A) in order to obtain group index of the soil plastic limit must be computed from the graph that developed by number of blows verses water content computed. Therefore, we can read plastic limit from the graph at number of blows is 25.

Figure 4.5 Liquid Limit data plot for Malka Jabdu Site

From figure 4.5, At number of blows is equal to 25 we can read the value of Liquid limit is equal to 44.1%. By the procedure Liquid limit of all samples at number of blows are equal 25 summarized as bellows.

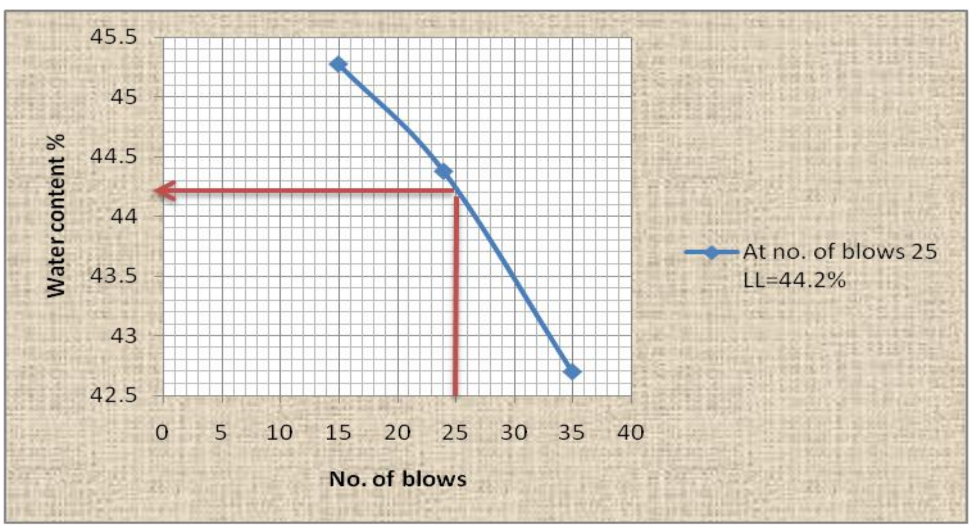

Figure 4.6 Liquid Limit plot for Bargale soils

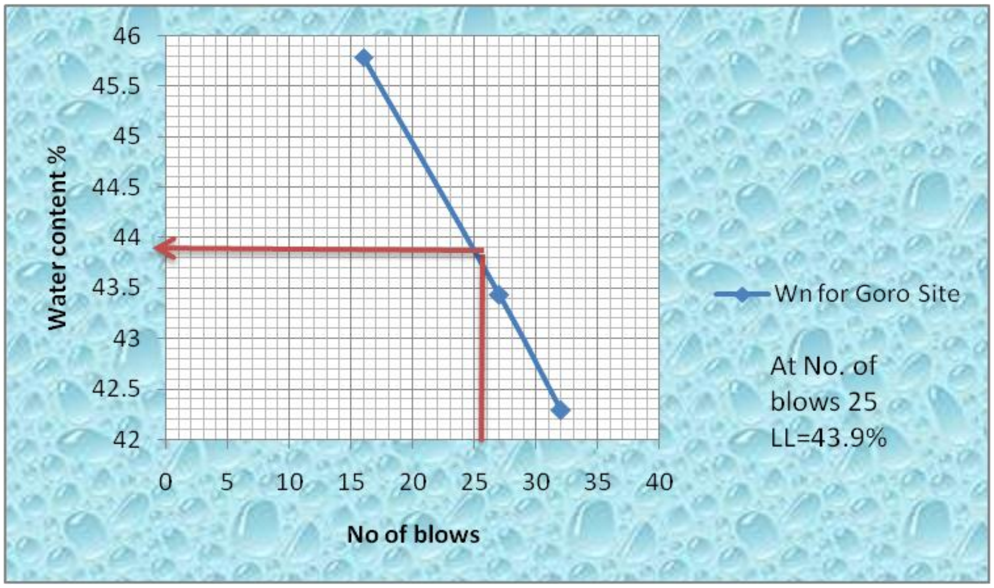

Figure 4.7 Liquid Limit Plot For Goro Site Soils.

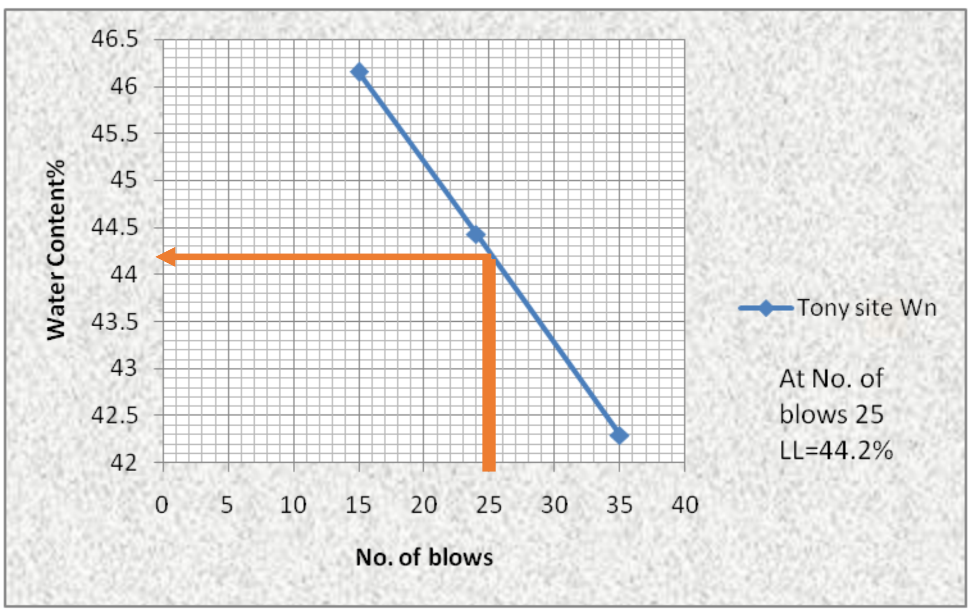

Figure 4.8 Liquid Limit analysis Tony soils.

Figure 4.9 Liquid Limit plot for Ganda kore soils.

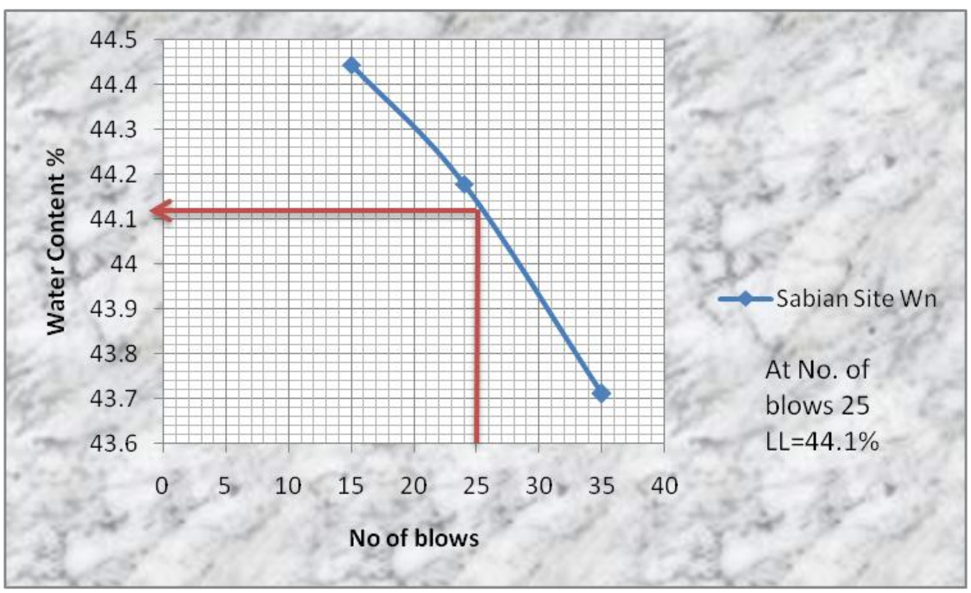

Figure 4.10 Liquid Limit plot for soils at sabian

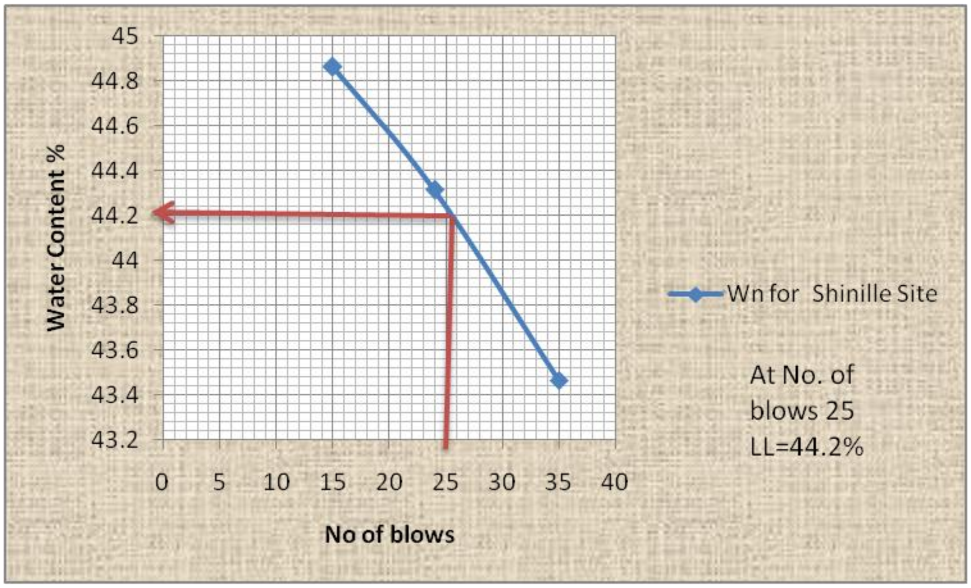

Figure 4.11 Liquid Limit Plot curve for Shinille Site

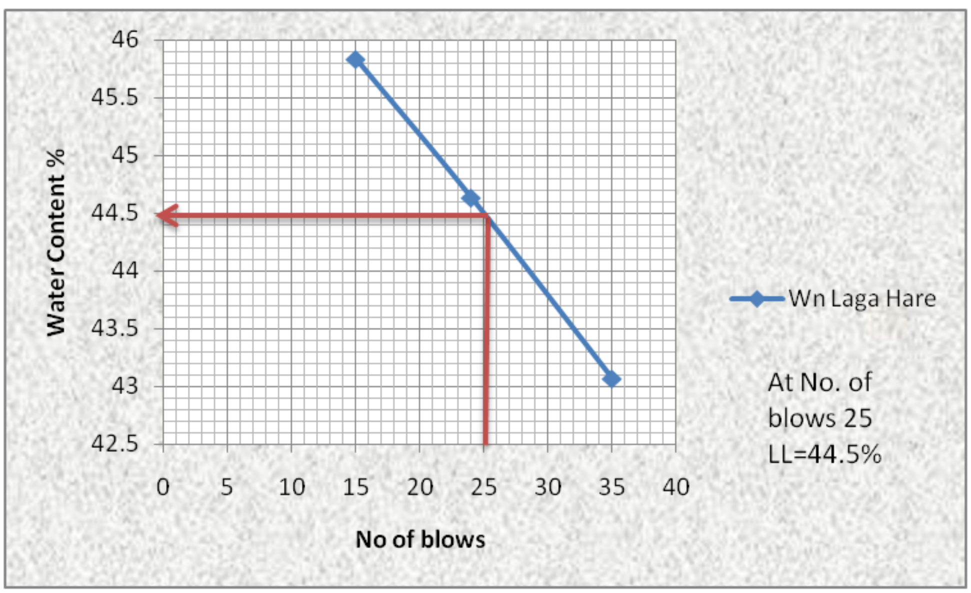

Figure 4.12 Liquid Limit plot curve for Laga Hare soils.

The liquid limit test on oven dry sample was done only on five representative samples. These values are required, to know the ratio of liquid limit on oven dried and air dried sample, which will intern used to classify the soil as organic and inorganic. The oven drying samples were prepared by putting the sample in an oven for 24 hours at a temperature of 110 ºc + 5º.

The Atterberg Limits for soil in guguba soils are summarized in Table 4.5 and the liquid limits for oven dried samples are given in Table 4.6. From this we can observe that liquid limit ranges from 43-45%, plastic limit ranges from 27-29% and plastic index from 15-17 %

Table 4.5 Atterberg Limit Results Summery for air dried Soil samples

Serial No	Designation	Liquid Limit %	Plastic Limit %	Plastic Index %
1	Tp1	44.1	28.56	15.54
2	Tp2	44.2	28.30	15.90
3	Tp3	43.9	27.1	16.80
4	Tp4	44.2	27.63	16.57
5	Tp5	44.4	27.89	16.51
6	Tp6	44.1	27.18	15.92
7	Tp7	44.2	28.01	16.19
8	Tp8	44.5	28.56	15.94

Table 4.6. The ratio of liquid limit on oven dried and air dried representative

Test Pits	Oven dried	Air dried	Ratio
Tp1	42	44.1	95
Tp3	43	43.9	98
Tp5	40	44.4	90
Tp7	41	44.2	92
Tp8	43	44.5	97

The soils under investigation have been classified according to AASHTO M-145 and Unified Soil Classification system. The summery of laboratory results was stated on table 4.7 as follows.

4.1.3.2 Classification of soils based on Unified soil classification (USC) system

This system describes a system for classifying minerals and organo-mineral soils for engineering purposes based on laboratory determination of particle-size characteristics, liquid limit, and plasticity index and shall be used when precise classification is required.

Table 4.7 Classifications of soils based on USC Classification system

serial No	Designation	Percent amount of particle size				LL (%)	PI (%)	According to USCS
		Gravel	Sand	silt	Clay			
1	Tmj	9.52	46.33	29.14	15.01	44.1	15.54	ML
2	Tbr	8.51	46.15	35.61	9.73	44.2	15.90	ML
3	Tgr	5.33	55.38	29.89	9.4	43.9	16.80	CL
4	Ttn	6.706	49.61	31.81	11.88	44.2	16.57	CL
5	Tgk	3.10	46.53	39.09	11.28	44.4	16.51	mL
6	Tsb	7.27	37.72	50.87	7.26	44.1	15.92	ML
7	Tsh	4.15	49.80	29.57	15.33	44.2	16.19	ML
8	Tlh	7.65	47.45	27.83	17.07	44.5	15.94	ML

According to USC classification scheme most of the soil of the study area falls in ML or CL region, which shows that the soil is non expansive. From the plot of plasticity chart in figure 4.13 and the classification soils on table above the guguba soils found in Dire Dawa town are silt and clay. And also shows inorganic clays of medium plasticity.

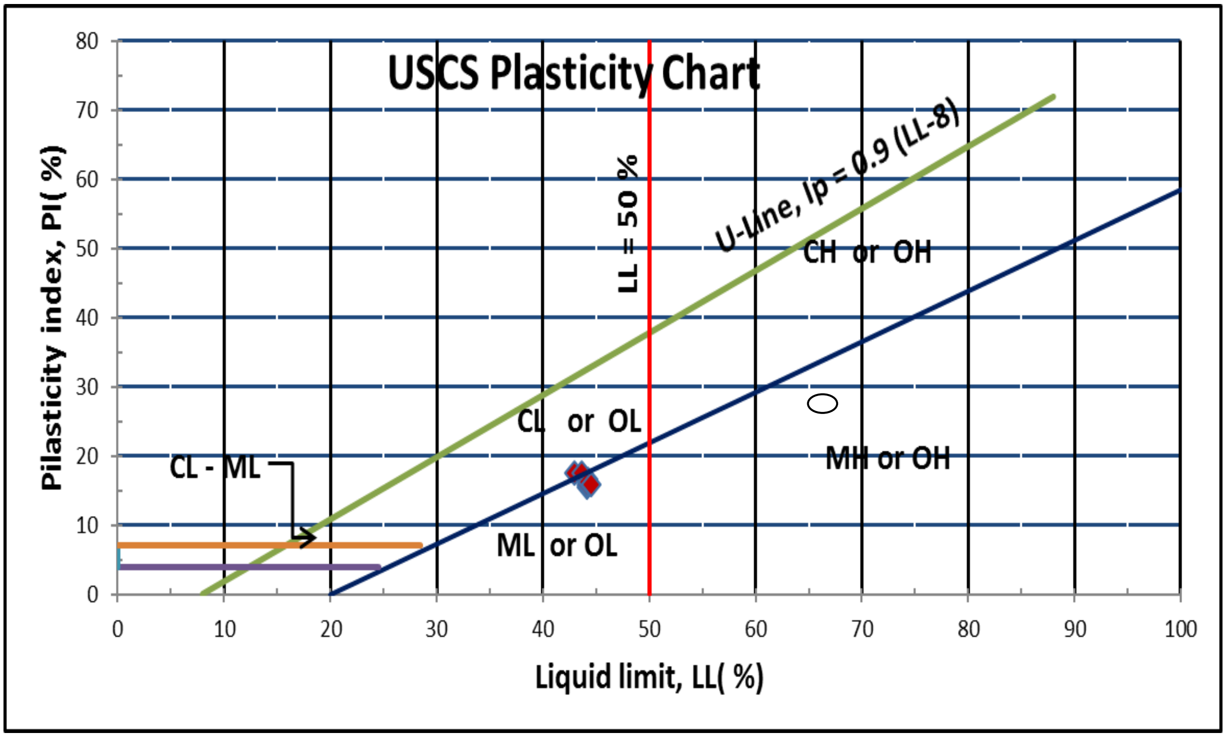

Figure 4.13 Plasticity chart of the study area according to Unified Soil Classification System

4.1.3.3 Classifications of soils based on AASHTO Classification system

The AASHTO system uses similar techniques as that of USC but the dividing line has an equation of the form PI= LL-30. It generally classifies a soil broadly into granular material and silt-clay material. The granular material is further divided into three groups which are called A-1, A-2 and A-3. The silt-clay material is in turn divided into four groups namely, A-4, A-5, A-6 and A-7.

As it can be observed from this Classification system (Table 4.7 and Table 2.2) the usual types of significant constituent materials are clayey soils. Which exhibits general rating as subgrade was poor and classified under A-7-6 group index.

Table 4.8 AASHTO classifications the samples

serial No	Designation	Percent passing Sieves			LL (%)	PI (%)	Group Index	Group Classification	Usual types of significant constituent materials	General rating as subgrade materials
		No. 10	No. 40	No. 200						
1	Tmj	83.62	67.94	44.11	44.1	15.54	4(max)	A-7-6	Clayey soils	Poor
2	Tbr	85.59	67.82	45.31	44.2	15.90	4(max)	A-7-6	Clayey soils	Poor
3	Tgr	85.78	68.53	39.26	43.9	16.80	3(max)	A-7-6	Clayey soils	Poor
4	Ttn	85.41	66.48	43.65	44.2	16.57	4(max)	A-7-6	Clayey soils	Poor
5	Tgk	89.23	67.89	50.35	44.4	16.51	6(max)	A-7-6	Clayey soils	Poor
6	Tsb	86.35	64.95	44.42	44.1	15.92	4(max)	A-7-6	Clayey soils	Poor
7	Tsh	93.53	70.40	45.91	44.2	16.19	4(max)	A-7-6	Clayey soils	Poor
8	Tlh	85.29	66.71	44.75	44.5	15.94	4(max)	A-7-6	Clayey soils	Poor

4.1.4 Free Swell

Free swell test results for oven dried samples at a temperature of105+5 ^{o}c are summarized in Table below. From the test result one can see that the free swell of the soil under investigation ranges from 20.5% to 47%. Those soils having a free swell less than 50% are considered as low in degree of expansion. Hence all soil samples under investigation are non-expansive soils.

Table 4.9 Free swell test results of the guguba soil

Serial no	Designation	Test Condition	Free swell	Water Used for testing
1	Tmj	Oven Dry	27.50	Tap Water
2	Tbr	Oven Dry	46	Tap Water
3	Tgr	Oven Dry	20.50	Tap Water
4	Ttn	Oven Dry	47	Tap Water
5	Tgk	Oven Dry	28	Tap Water
6	Tsb	Oven Dry	32	Tap Water
7	Tsh	Oven Dry	31.50	Tap Water
8	Tlh	Oven Dry	32	Tap Water

4.1.5 Compaction

From the test results the maximum dry density (MDD) of gugba soil ranges from1.26 to 1.51 g/cm3 and the optimum moisture content ranges 17.5 to 36.5 percent. The summary of the test result is shown in table 4.10.

Generally, course grained soils can be compacted to a higher dry density than fine gained soils for some compaction effort. When some fines are added to the coarse grained soils to file the voids, the maximum dry density further increases, but it the amount of fines is too much, more than required to fill the voids, it results in reduction of dry density; well graded soils can attain higher dry density than poorly graded soils. This can also be observed from Table 4.3 and Table 4.10 below i.e. as the amount of courser particles increases the dry density will increase too. That is why samples with designation Tmj and Tlh show higher dry density as compared to other samples.

Table 4.10 Summary of Optimum moisture content and the maximum dry density

Serial No.	Designation	Maximum Dry Density (g/cm3)	Optimum Moisture Content (g/cm3)
1	Tmj	1.51	34.65
2	Tbr	1.40	23.50
3	Tgr	1.30	26.79
4	Ttn	1.33	28.75
5	Tgk	1.26	29.45
6	Tsb	1.44	23.62
7	Tsh	1.35	27.09
8	Tlh	1.45	30.95

4.1.6 Laboratory Unconfined Compression Test

From the test results unconfined compression tests the unconfined compression strength of guguba soil ranges from 233.27 Kpa-568.7 kpa and its evident that the shear strength or cohesion of the soils ranges 116.63 kpa to 284.35 Kpa as shown in table 4.11.

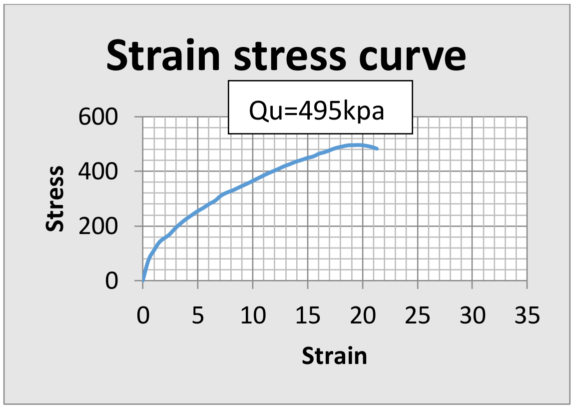

Figure 4.14 Stress strain curve for malka jabdu soils

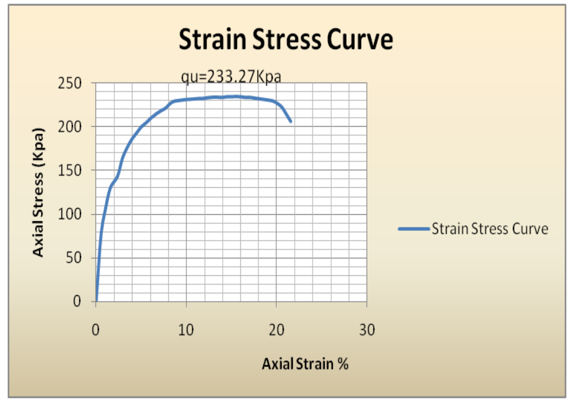

Figure 4.15 Axial Strain Stress Chart for Bargale Site

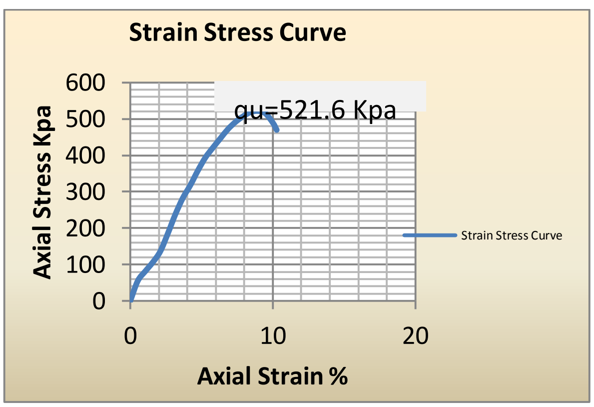

Figure 4.16 Strain Stress for Goro Soils

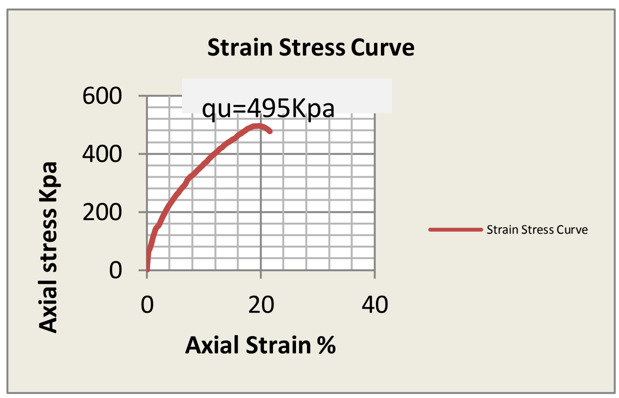

Figure 4.17 Axial Strain Stress Chart for Tony Soil.

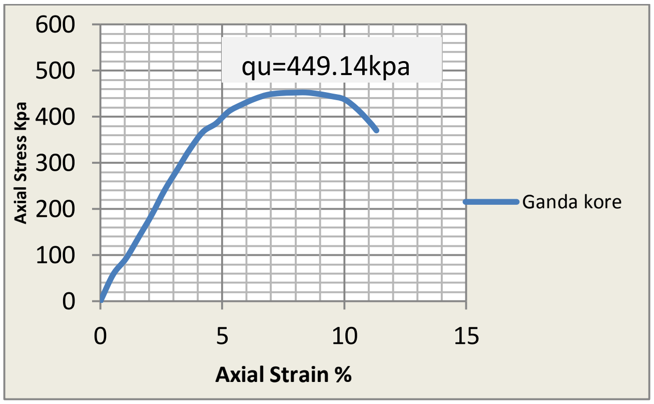

Figure 4.18 Axial Strain stress chart for ganda Kore soil

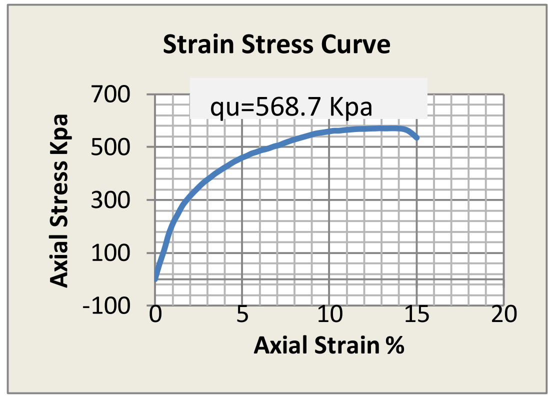

Figure 4.19 Axial Strain stress chart for shinille

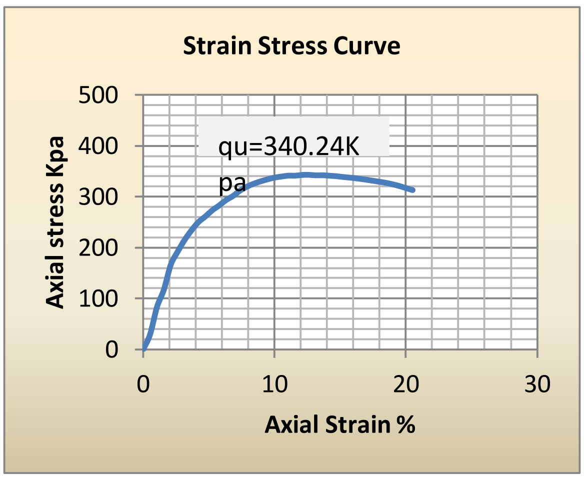

Figure 4.20 Axial Strain stress chart for Laga Hare

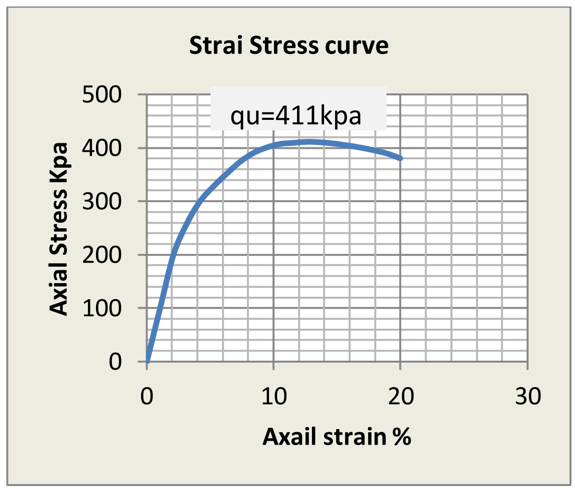

Figure 4.21 Axial Strain stress chart for sabian soil

Table 4.11 Summary of Maximum Unconfined strength and Shear Strength

Serial No	Designation	Maximum load at which the soil fail Qu(Kpa)	Cu (Kpa)=qu/2
1	Tmj	495	247.5
2	Tbr	233.27	116.63
3	Tgr	521.6	260.8
4	Ttn	495	247.5
5	Tgk	449.14	224.57
6	Tsb	411	205.5
7	Tsh	568.7	284.35
8	Tlh	340.24	170.12

4.2 Discussions of the laboratory test results

From Table 4.2, The specific gravity of soil becomes lower when it contains organic matter. That is why the soil samples from ganda kore has specific gravity around 2.30 which shows the soils have gypsum constitute material suitable for the production of cement. But the rest of the samples have specific gravity becomes between 2.50 to 2.65.

From grain size analysis shown in figures 4.1, 4.2, 4.3, 4.4 and Table 4.3, the results obtained indicate that the dominant proportion of soil particle in the research area is silt, which has clay content ranging from 7.26-17.07%%, silt fraction 27.83-50.87%, sand fraction 37.72-49.80% and gravel content from 3.10-9.52%.

The result of Atterberg Limit of the soil samples on air dried and oven dried soil samples is shown on Table 4.5 and 4.6. From these testes the soil under investigation is inorganic. The soil in the research area has liquid limit ranging from 43-45%, plastic limit ranging from 27-29% and plastic index from 15-17%.

Free swell test results for oven dried samples at a temperature of 105+5 ^{o}c are summarized in Table 4.9. From the test result one can see that the free swell of the soil under investigation ranges from 20.50% to 47%. Those soils having a free swell less than 50% are considered as low in degree of expansion. Hence all soil samples under investigation are non-expansive soils.

Table 4.7 shows plasticity chart of the study area according to Unified Soil Classification System. This shows that the soil under investigation lies below the A-line in the region of inorganic silt and inorganic elastic silt. That means inorganic silt with low to medium plasticity. This table also shows that sample located above A-line, it is because of some organic content of the sample.

Table 4.8 Shows according to AASHTO Classifications system the study area (guguba soils) was classified in group A-7-6. From this study due to More than 35 percent passing through sieve number 200 in all samples of the soil was Silt-clay materials which was clayey soils. From all over data collected the group index of soil sample take from Goro site and Ganda Kore site was different. Soils existed in six sites exhibit similar characteristics. The rest of the laboratory computation shows that the soil can be classified under A-7-6(4).

A cohesion less soil has zero plasticity index. Such soil as termed as non-plastic. Accordingly, guguba soils has medium plastic and possess a medium plastic index. Soils possessing from 7 to 17 values of plastic index can be medium plastic.

Hence, Atterberg classifies the soils according to their plasticity for PI equal to zero the soils are non-plastic; for PI less than 7 it has low plastic; for PI lies between 7 to 17 it was medium plastic and for PI was greater than 17 the soils exhibit high plastic.

Optimum moisture content and the maximum dry density of the study area is summarized in Table 4.10. From the test results the maximum dry density (MDD) of guguba soils ranges from1.26 to 1.51 g/cm3 and the optimum moisture content ranges 23.50 to 34.65 percent.

From the analysis of unconfined compression tests the mechanical properties of this fine grained soils and shearing resistances were obtained. Accordingly the unconfined compression strength of guguba soil ranges from 233.27 Kpa-568.7 kpa and its evident that the shear strength or cohesion of the soils ranges 116.63 kpa to 284.35 Kpa .

CHAPTER 5

5.1 CONCLUSION AND RECOMMENDATION

5.1.1 Conclusion

The research was conducted to find engineering classification of guguba soils within the scope of the study. Accordingly, the required laboratory tests were conducted on samples retrieved from different geographical area of Dire Dawa. Using the obtained eight test results the groups the soils are identified.

1) From specific gravity, the soils existed at ganda kore has specific gravity of 2.30 which shows the soils have gypsum constitute materials that was suitable for the production of cement. But the rest of the samples have specific gravity becomes between 2.50 to 2.65.

2) The grain size analysis classification systems of samples taken showed that guguba soils found in kebeles of the city was mostly silt materials. And silty sand soils in which the percentage of clay ranges from 7.26-17.07%, silt from 29.14-50.87%, sand from 37.22-49.80 % and gravel 0-25%.

3) This soils have similar engineering properties and the same group classification i.e. A-7-6. That 75% of the soils are lied under group of A-7-6 (4), 12.5% of the soils was A-7-6(3) and 12.5% of the soils was A-7-6(6). Which is fine grained soils.

4) Its plastic index exhibits that the soils have medium plastic values based on Atterberg classification for plastic index lies between 7 to 17, which shows the soil was cohesive.

5) Almost all the samples have free swell value of less than 50%. This shows the soil in the study area is non expansive with free swell value ranging from 20.5-46%.

6) The unconfined compression strength of guguba soil ranges from 233.27 Kpa-568.7 kpa and its evident that the shear strength or cohesion of the soils ranges 116.63 kpa to 284.35 Kpa. That shows guguba soils are very stiff and hard.

5.1.2 Recommendations

The exposure encountered in trying to conduct the current research has revealed areas where further efforts may be proved in the future. Following are some of the recommendations in relation to the subject study:

1. It is recommended to carry out this classification with a large number of samples including geographical areas in Dire Dawa which are not covered by this research.
2. Further, it is advisable to develop study on this unique soil in order to produce HCB by reducing/instead of/ the amount cement used.
3. The results of this study may not be adequate for implementation of specific projects and, hence, the current findings should be supplemented with more detailed studies.

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Appendix A

Atterberg Limit Tests Data

Soil Testing Laboratory

Atterberge Limits For Malka Jabdu

[A] Liquid Limit

Determination No.	1	2	3
Number of drops	35	24	15
Can No.	Aa	bb	cc
Mass of can + Moist Soil, g	21.74	21.18	24.15
Mass of can + dry soil, g	17.70	17.27	19.23
Mass of can, g	8.32	8.42	8.33
Mass of water	4.04	3.91	4.92
Mass of dry soil, g	9.38	8.85	10.9
Moisture content, w(%)	43.07036	44.18079	45.13761
From the flow curve or from equations, LL=44.1%			

[B] Plastic Limit

Determination No.	1	2
Can no.	A1	B1
Mass of can + Moist Soil, g	14.72	14.07
Mass of can + dry soil, g	13.28	12.76
Mass of can, g	8.22	8.19
Mass of water, g	1.44	1.31
Mass of dry soil, g	5.06	4.57
Water content, w(%)	28.46	28.66
Plastic limit(%) = 28.56%		

Liquid Limit = -----------44.1%

Plastic Limit = ------------28.56%

Plasticity Index = ---------15.54

Soil Testing Laboratory

Atterberge Limits For Bargale Site

[A] Liquid Limit

Determination No.	1	2	3
Number of drops	35	24	15
Can No.	A	B	C
Mass of can + Moist Soil, g	22.59	22.28	24.15
Mass of can + dry soil, g	18.32	22.28	19.22
Mass of can, g	8.32	8.42	8.33
Mass of water	4.27	4.26	4.93
Mass of dry soil, g	10	9.6	10.89
Moisture content, w(%)	42.7	44.375	45.27
From the flow curve or from equations, LL=44.2%			

[B] Plastic Limit

Determination No.	1	2
Can no.	AA	BB
Mass of can + Moist Soil, g	15.52	14.58
Mass of can + dry soil, g	13.98	13.11
Mass of can, g	8.22	8.19
Mass of water, g	1.54	1.47
Mass of dry soil, g	5.76	4.92
Water content, w(%)	26.73	29.88
Plastic limit(%)	28.30%	

Liquid Limit = -----------44.2%

Plastic Limit = ------------28.30%

Plasticity Index = ---------15.90

Soil Testing Laboratory

Atterberge Limits Goro Site

[A] Liquid Limit

Determination No.	1	2	3
Number of drops	32	27	16
Can No.	A	B	C
Mass of can + Moist Soil, g	30.98	31.87	32.12
Mass of can + dry soil, g	24.26	24.76	25
Mass of can, g	8.37	8.39	9.45
Mass of water	6.72	7.11	7.12
Mass of dry soil, g	15.89	16.37	15.55
Moisture content, w(%)	42.29075	43.43311	45.78778
From the flow curve or from equations, LL=43.9%			

[B] Plastic Limit

Determination No.	1	2
Can no.	GA	GB
Mass of can + Moist Soil, g	14.63	13.92
Mass of can + dry soil, g	13.25	12.73
Mass of can, g	8.29	8.22
Mass of water, g	1.38	1.19
Mass of dry soil, g	4.96	4.51
Water content, w(%)	27.82	26.39
Plastic limit(%)	27.1%	

Liquid Limit = 43.9%

Plastic Limit = 27.1%

Plasticity Index =16.8

Soil Testing Laboratory

Atterberge Limits Tony Site

[A] Liquid Limit

Determination No.	1	2	3
Number of drops	35	24	15
Can No.	A	B	C
Mass of can + Moist Soil, g	21.98	22.56	23.72
Mass of can + dry soil, g	17.92	18.21	18.86
Mass of can, g	8.32	8.42	8.33
Mass of water	4.06	4.35	4.86
Mass of dry soil, g	9.60	9.79	10.53
Moisture content, w(%)	42.29167	44.43309	46.15385
From the flow curve or from equations, LL = 44.2%			

[B] Plastic Limit

Determination No.	1	2
Can no.	TA	TB
Mass of can + Moist Soil, g	14.31	14.22
Mass of can + dry soil, g	12.88	13.03
Mass of can, g	8.22	8.19
Mass of water, g	1.43	1.19
Mass of dry soil, g	4.66	4.84
Water content, w(%)	30.68	24.58
Plastic limit(%)	27.63	

Liquid Limit =44.2 % Plastic Limit = 27.63%

Plasticity Index = 16.57

Soil Testing Laboratory

Atterberge Limits Ganda Kore

[A] Liquid Limit

Determination No.	1	2	3
Number of drops	35	24	15
Can No.	AA	BB	CC
Mass of can + Moist Soil, g	22.11	22.97	23.44
Mass of can + dry soil, g	17.91	18.49	18.76
Mass of can, g	8.32	8.42	8.33
Mass of water	4.2	4.48	4.68
Mass of dry soil, g	9.59	10.07	10.49
Moisture content, w(%)	43.79562	44.490858	44.87057
From the flow curve or from equations, LL = 44.4%			

[B] Plastic Limit

Determination No.	1	2
Can no.	GKA	GKB
Mass of can + Moist Soil, g	14.29	14.23
Mass of can + dry soil, g	12.91	12.97
Mass of can, g	8.22	8.19
Mass of water, g	1.38	1.26
Mass of dry soil, g	4.69	4.78
Water content, w(%)	29.42	26.36
Plastic limit(%)	27.89%	

Liquid Limit = 44.4% Plastic Limit = 27.89%

Plasticity Index = 16.51

Soil Testing Laboratory

Atterberge Limits for Sabian Site

[A] Liquid Limit

Determination No.	1	2	3
Number of drops	35	24	15
Can No.	A	B	C
Mass of can + Moist Soil, g	22.26	22.91	23.02
Mass of can + dry soil, g	18.02	18.47	18.5
Mass of can, g	8.32	8.42	8.33
Mass of water	4.24	4.44	4.52
Mass of dry soil, g	9.7	10.05	10.17
Moisture content, w(%)	43.71134	44.1791	44.4444
From the flow curve or from equations, LL = 44.1%			

[B] Plastic Limit

Determination No.	1	2
Can no.	SA	SB
Mass of can + Moist Soil, g	13.65	13.68
Mass of can + dry soil, g	12.51	12.42
Mass of can, g	8.22	8.19
Mass of water, g	1.14	1.26
Mass of dry soil, g	4.29	4.23
Water content, w(%)	26.57	29.78
Plastic limit(%)	28.18	

Liquid Limit = 44.1%

Plastic Limit = 28.18%

Plasticity Index = 15.92

Soil Testing Laboratory

Atterberge Limits for Shinille Site

[A] Liquid Limit

Determination No.	1	2	3
Number of drops	35	24	15
Can No.	A	B	C
Mass of can + Moist Soil, g	21.82	23.01	22.28
Mass of can + dry soil, g	17.73	18.53	17.96
Mass of can, g	8.32	8.42	8.33
Mass of water	4.09	4.48	4.32
Mass of dry soil, g	9.41	10.1	9.63
Moisture content, w(%)	43.4644	44.31256	44.85981
From the flow curve or from equations, LL = 44.1%			

[B] Plastic Limit

Determination No.	1	2
Can no.	SA	SB
Mass of can + Moist Soil, g	13.98	13.27
Mass of can + dry soil, g	12.44	12.44
Mass of can, g	8.22	8.19
Mass of water, g	1.54	0.83
Mass of dry soil, g	4.22	4.25
Water content, w(%)	36.46	19.53
Plastic limit(%)	28.01	

Liquid Limit = 44.1% Plastic Limit = 28.01%

Plasticity Index = 16.19

Soil Testing Laboratory

Atterberge Limits For Laga Hare Site

[A] Liquid Limit

Determination No.	1	2	3
Number of drops	35	24	15
Can No.	LHA	LHB	LHC
Mass of can + Moist Soil, g	21.74	21.22	24.28
Mass of can + dry soil, g	17.70	17.27	19.22
Mass of can, g	8.32	8.42	8.33
Mass of water	4.04	3.95	5.06
Mass of dry soil, g	9.38	8.85	11.04
Moisture content, w(%)	43.07	44.633	45.833
From the flow curve or from equations, LL = 44.5%			

[B] Plastic Limit

Determination No.	1	2
Can no.	AA	BB
Mass of can + Moist Soil, g	14.72	14.07
Mass of can + dry soil, g	13.28	12.76
Mass of can, g	8.22	8.19
Mass of water, g	1.44	1.31
Mass of dry soil, g	5.06	4.57
Water content, w(%)	28.46	28.67
Plastic limit	28.56	

Liquid Limit = 44.5% Plastic Limit = 28.56 %

Plasticity Index = 15.94

Appendix B

Sieve Analysis Data

Sieve Analysis Data at Malka Jabdu Site

Sieve Number	Diameter (mm)	Mass of empty sieve(g)	Mass of sieve+ soil Retained(g)	Soil Retained(g)	Percent retained	Percent passing
4	4.75	116.23	192.45	76.22	9.5275	90.48
10	2	99.27	154.08	54.81	6.85125	83.62875
20	0.84	97.58	161.89	64.31	8.03875	75.59
40	0.425	98.96	160.12	61.16	7.645	67.945
60	0.25	91.46	127.09	35.63	4.45375	63.49125
140	0.106	93.15	232.16	139.01	17.37625	46.115
200	0.075	90.92	106.9	15.98	1.9975	44.1175
pan		70.19	423.06	352.87	44.10875	0.00875
				799.99	99.99875	

Sieve Analysis at Bargale site

Sieve Number	Diameter (mm)	Mass of empty sieve(g)	Mass of sieve+ soil Retained(g)	Soil Retained(g)	Percent retained	Percent passing
4	4.75	116.23	184.31	68.08	8.51	91.5
10	2	99.27	146.51	47.24	5.905	85.595
20	0.84	97.58	170.61	73.03	9.12875	76.46625
40	0.425	98.96	168.07	69.11	8.63875	67.8275
60	0.25	91.46	120	28.54	3.5675	64.26
140	0.106	93.15	220.37	127.22	15.9025	48.3575
200	0.075	90.92	115.27	24.35	3.04375	45.31375
pan		70.19	432.62	362.43	45.30375	0.01
				800	100	

Sieve Analysis at Goro site

Sieve Number	Diameter (mm)	Mass of empty sieve(g)	Mass of sieve+ soil Retained(g)	Soil Retained(g)	Percent retained	Percent passing
4	4.75	116.23	158.92	42.69	5.33625	94.67
10	2	99.27	170.32	71.05	8.88125	85.78875
20	0.84	97.58	152.28	54.7	6.8375	78.95125
40	0.425	98.96	182.3	83.34	10.4175	68.53375
60	0.25	91.46	137.88	46.42	5.8025	62.73125
140	0.106	93.15	206.12	112.97	14.12125	48.61
200	0.075	90.92	165.71	74.79	9.34875	39.34125
pan		70.19	384.22	314.03	39.25375	0.0075
				799.99	99.99875	

Sieve Analysis at Tony Site

Sieve Number	Diameter (mm)	Mass of empty sieve(g)	Mass of sieve+ soil Retained(g)	Soil Retained(g)	Percent retained	Percent passing
4	4.75	116.23	219.88	103.65	12.9563	87.0438
10	2	99.27	162.35	63.08	7.885	79.1588
20	0.84	97.58	104.2	6.62	0.8275	78.3313
40	0.425	98.96	143.75	44.79	5.59875	72.7325
60	0.25	91.46	154.73	63.27	7.90875	64.8238
140	0.106	93.15	150.47	57.32	7.165	57.6588
200	0.075	90.92	203.04	112.12	14.015	43.6438
pan		70.19	419.34	349.15	43.6438	0
				800	100	

Sieve Analysis at Ganda Kore Site

Sieve Number	Diameter (mm)	Mass of empty sieve(g)	Mass of sieve+ soil Retained(g)	Soil Retained(g)	Percent retained	Percent passing
4	4.75	116.23	141.1	24.87	3.10875	96.89125
10	2	99.27	160.5	61.23	7.65375	89.2375
20	0.84	97.58	147.1	49.52	6.19	83.0475
40	0.425	98.96	220.16	121.2	15.15	67.8975
60	0.25	91.46	152.9	61.44	7.68	60.2175
140	0.106	93.15	131.82	38.67	4.83375	55.38375
200	0.075	90.92	131.18	40.26	5.0325	50.35125
pan		70.19	472.99	402.8	50.35	0.00125
				799.99	99.99875	

Sieve Analysis Data for Sabian Site

Sieve Number	Diameter (mm)	Mass of empty sieve(g)	Mass of sieve+ soil Retained(g)	Soil Retained(g)	Percent retained	Percent passing
4	4.75	116.23	174.45	58.22	7.2775	92.7225
10	2	99.27	150.18	50.91	6.36375	86.35875
20	0.84	97.58	182.02	84.44	10.555	75.80375
40	0.425	98.96	185.73	86.77	10.84625	64.9575
60	0.25	91.46	139.57	48.11	6.01375	58.94375
140	0.106	93.15	125.32	32.17	4.02125	54.9225
200	0.075	90.92	174.94	84.02	10.5025	44.42
pan		70.19	425.55	355.36	44.42	0
				800	100	

Sieve Analysis Data for Shinille Site

Sieve Number	Diameter (mm)	Mass of empty sieve(g)	Mass of sieve+ soil Retained(g)	Soil Retained(g)	Percent retained	Percent passing
4	4.75	116.23	149.46	33.23	4.15375	95.84625
10	2	99.27	117.73	18.46	2.3075	93.53875
20	0.84	97.58	169.8	72.22	9.0275	84.51125
40	0.425	98.96	211.84	112.88	14.11	70.40125
60	0.25	91.46	160.1	68.64	8.58	61.82125
140	0.106	93.15	147.78	54.63	6.82875	54.9925
200	0.075	90.92	163.54	72.62	9.0775	45.915
pan		70.19	437.51	367.32	45.915	0
				800	100	

Sieve Analysis Data for Laga Hare

Sieve Number	Diameter (mm)	Mass of empty sieve(g)	Mass of sieve+ soil Retained(g)	Soil Retained(g)	Percent retained	Percent passing
4	4.75	116.23	177.48	61.25	7.65625	92.34375
10	2	99.27	155.63	56.36	7.045	85.29875
20	0.84	97.58	166.17	68.59	8.57375	76.725
40	0.425	98.96	179.04	80.08	10.01	66.715
60	0.25	91.46	155.68	64.22	8.0275	58.6875
140	0.106	93.15	141.02	47.87	5.98375	52.70375
200	0.075	90.92	154.54	63.62	7.9525	44.75125
Pan		70.19	428.2	358.01	44.75125	0
				800	100	

Appendex C

Compaction Tests Figures

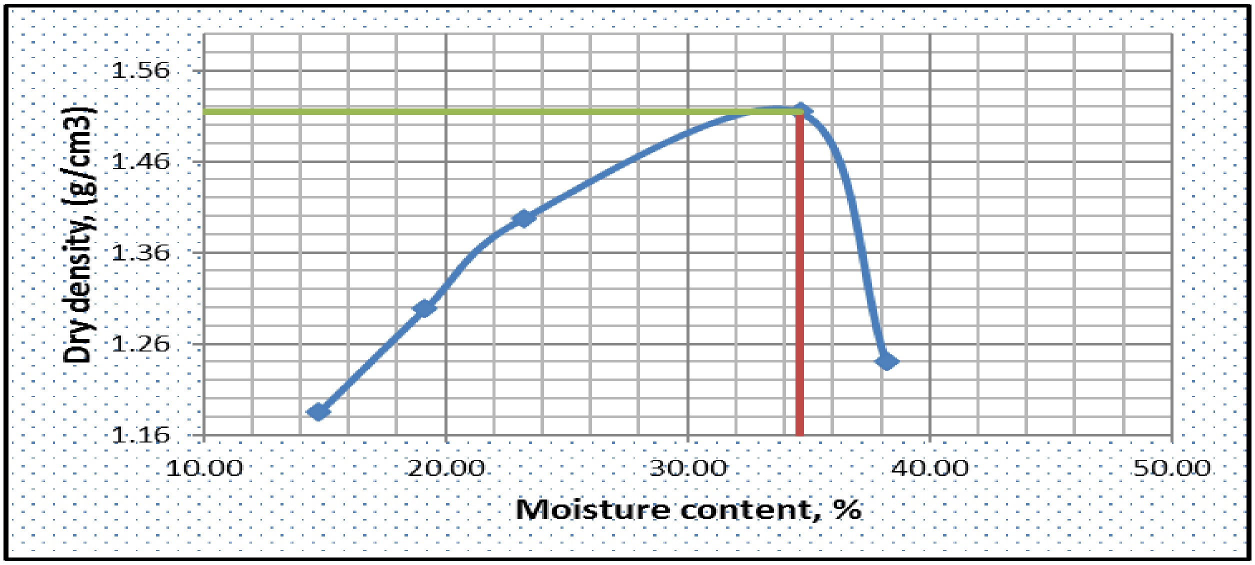


Figure C1 DD Vs Moisture contents for Malka Jabdu

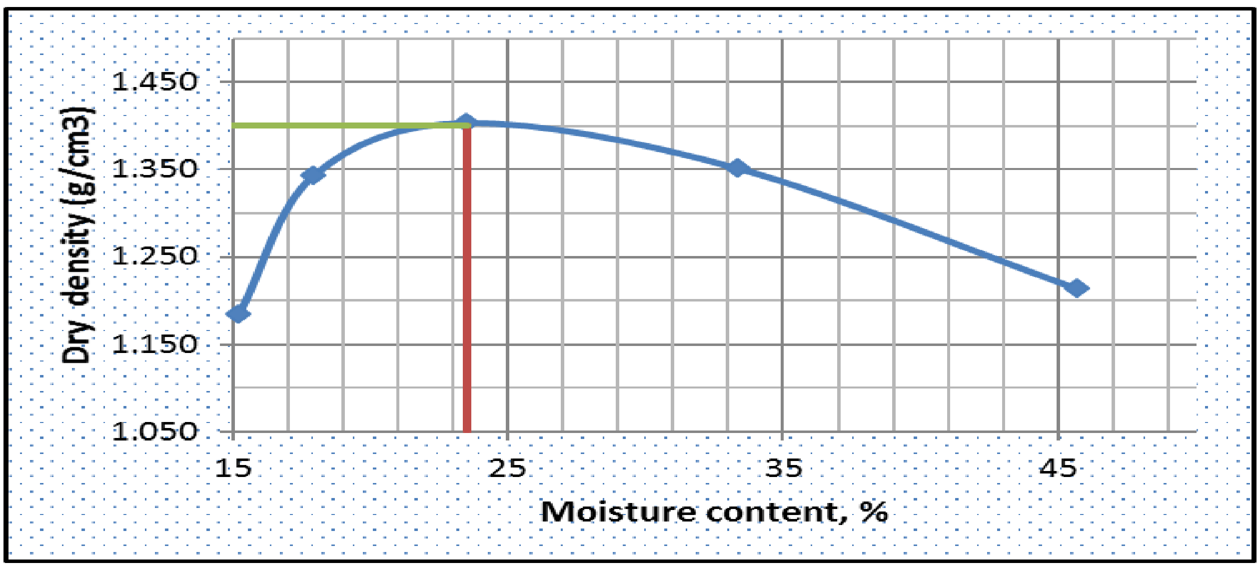


Figure C2 DD Vs Moisture contents for Bargale

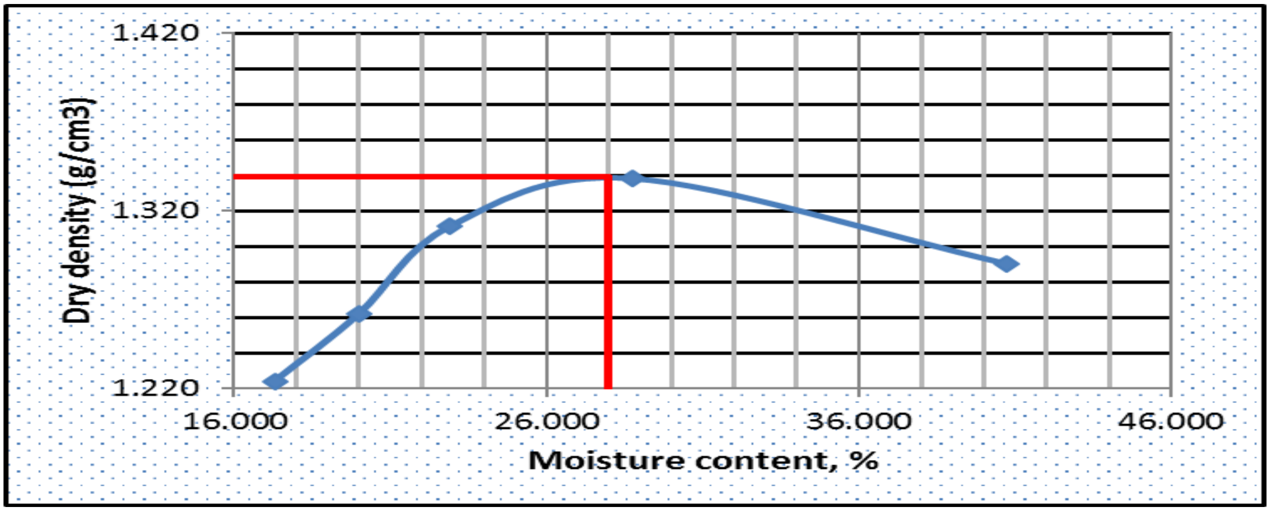


Figure C3 DD Vs Moisture contents for Tony samples

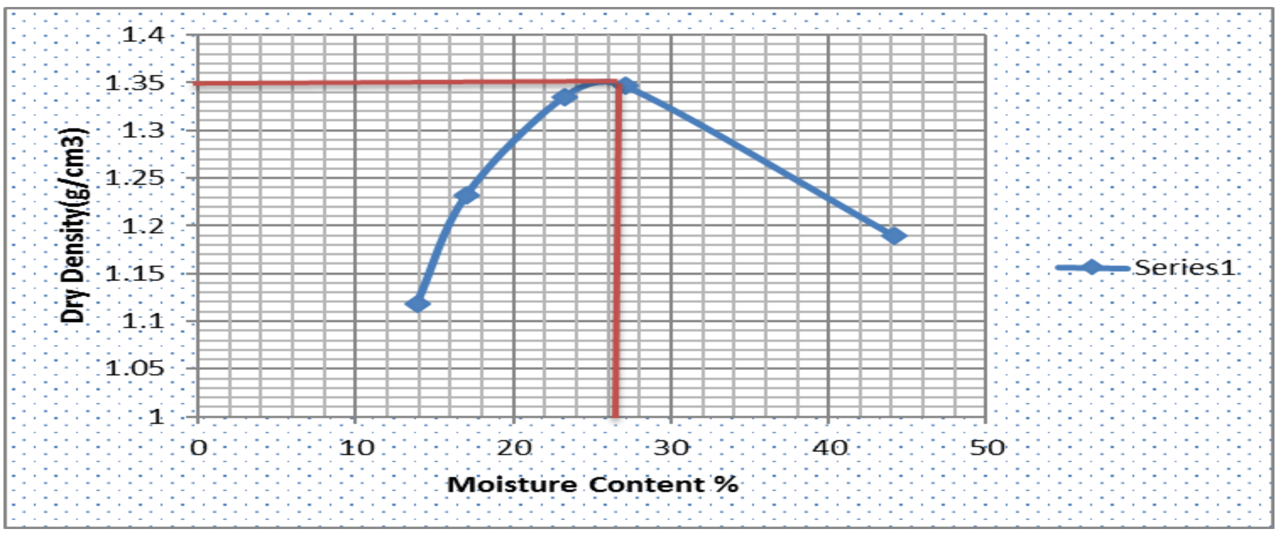


Figure C4 DD Vs Moisture contents for Shinille samples

Appendex D

Specific Gravity Tests for Selected Samples

SPECIFIC GRAVITY BY DENSITY BOTTLE @27 DEGREE CENTUGRADE

For Malka Jabdu Site

No	Observation	Determination		
		1	2	3
1	Wt of Density Bottle W1	16.94	16.94	16.94
2	Wt of Density Bottle + Dry Soil W2	32.12	41.1	38.5
3	Wt of Density Bottle + Dry Soil+ Water W3	84.67	89.9	88.62
4	Wt of Density Bottle + Distilled Water W4	75.62	75.62	75.62
5	Specific Gravity Gs	2.476346	2.445344	2.518692
6	Av. Gs	2.480127186		

For Bargale Site

No	Observation	Determination		
		1	2	3
1	Wt of Density Bottle W1	16.94	16.94	16.94
2	Wt of Density Bottle + Dry Soil W2	33.22	40.12	37.06
3	Wt of Density Bottle + Dry Soil+ Water W3	85.06	90.31	88.65
4	Wt of Density Bottle + Distilled Water W4	75.62	75.62	75.62
5	Specific Gravity Gs	2.380117	2.730271	2.8378
6	Av. Gs	2.649395861		

For Ganda Kore Site

No	Observation	Determination		
		1	2	3
1	Wt of Density Bottle W1	16.94	16.94	16.94
2	Wt of Density Bottle + Dry Soil W2	33.44	39.98	37.59
3	Wt of Density Bottle + Dry Soil+ Water W3	85.06	90.31	87.8
4	Wt of Density Bottle + Distilled Water W4	75.62	75.62	75.62
5	Specific Gravity Gs	2.33711	2.759281	2.438017
	Av. Gs	2.511469483		

For Tony Site

No	Observation	Determination		
		1	2	3
1	Wt of Density Bottle W1	16.94	16.94	16.94
2	Wt of Density Bottle + Dry Soil W2	35.6	41.1	42.4
3	Wt of Density Bottle + Dry Soil+ Water W3	86.22	89.44	89.78
4	Wt of Density Bottle + Distilled Water W4	75.62	75.62	75.62
5	Specific Gravity Gs	2.315136	2.336557	2.253097
	Av. Gs	2.301596961		

Appendix E

Unconfined Compression Strength Tests for selected samples

Malka Jabdu Soil Samples
Proving factor =1.34 Div/N= 0.00134KN; Displacement Factor .01div/mm

Axial Deformation (mm)	Strain (Ɛ)	Axial Strain (%)	Proving Ring Rading (Div)	Axial Load (KN)	Corrected Area (m2)	Axial Stress(Kpa)
0	0	0	0	0	0.001134	0
0.2	0.0026316	0.26315789	26	0.03484	0.00113699	61.28451
0.4	0.0052632	0.52631579	32	0.04288	0.00114	75.22807
0.6	0.0078947	0.78947368	39	0.05226	0.00114302	91.44166
0.8	0.0105263	1.05263158	48	0.06432	0.00114606	112.2451
1	0.0131579	1.31578947	55	0.0737	0.00114912	128.2721
1.2	0.0157895	1.57894737	61.5	0.08241	0.00115219	143.049
1.6	0.0210526	2.10526316	67	0.08978	0.00115839	155.0086
1.8	0.0236842	2.36842105	72	0.09648	0.00116151	166.1287
2	0.0263158	2.63157895	77	0.10318	0.00116465	177.1865
2.2	0.0289474	2.89473684	82	0.10988	0.0011678	188.1821
2.4	0.0315789	3.15789474	86	0.11524	0.00117098	196.8269
2.6	0.0342105	3.42105263	91	0.12194	0.00117417	207.7044
2.8	0.0368421	3.68421053	95	0.1273	0.00117738	216.2434
3	0.0394737	3.94736842	99	0.13266	0.0011806	224.7327
3.2	0.0421053	4.21052632	102.5	0.13735	0.00118385	232.0403
3.4	0.0447368	4.47368421	106	0.14204	0.00118711	239.3044
3.6	0.0473684	4.73684211	109.5	0.14673	0.00119039	246.5249
3.8	0.0500000	5	113	0.15142	0.00119368	253.7019
4	0.0526316	5.26315789	116.5	0.15611	0.001197	260.8354
4.2	0.0552632	5.52631579	119	0.15946	0.00120033	265.6927
4.6	0.0605263	6.05263158	126	0.16884	0.00120706	279.7544
4.8	0.0631579	6.31578947	129	0.17286	0.00121045	285.6129
5	0.0657895	6.57894737	132	0.17688	0.00121386	291.4341
5.2	0.0684211	6.84210526	135.5138	0.18158849	0.00121729	298.3492
5.4	0.0710526	7.10526316	141	0.18894	0.00122074	309.5508
5.6	0.0736842	7.36842105	144	0.19296	0.0012242	315.2414
6	0.0789474	7.89473684	149	0.19966	0.0012312	324.334
6.2	0.0815789	8.15789474	151.5	0.20301	0.00123473	328.8336
6.4	0.0842105	8.42105263	154	0.20636	0.00123828	333.3021
6.6	0.0868421	8.68421053	157	0.21038	0.00124184	338.8186
6.8	0.0894737	8.94736842	160	0.2144	0.00124543	344.2978
7	0.0921053	9.21052632	162.5	0.21775	0.00124904	348.6668
7.2	0.0947368	9.47368421	165.5	0.22177	0.00125267	354.0744
7.4	0.0973684	9.73684211	168	0.22512	0.00125633	358.3782
7.6	0.1000000	10	171.5	0.22981	0.00126	364.7778

7.8	0.1026316	10.2631579	174	0.23316	0.0012637	369.0131
8	0.1052632	10.5263158	176.5	0.23651	0.00126741	373.2173
8.4	0.1105263	11.0526316	183	0.24522	0.00127491	384.6856
8.6	0.1131579	11.3157895	186	0.24924	0.00127869	389.8351
8.8	0.1157895	11.5789474	189	0.25326	0.0012825	394.9474
9	0.1184211	11.8421053	191.5	0.25661	0.00128633	398.9806
9.2	0.1210526	12.1052632	194	0.25996	0.00129018	402.9826
9.4	0.1236842	12.3684211	197	0.26398	0.00129405	407.9891
9.6	0.1263158	12.6315789	200	0.268	0.00129795	412.9583
9.8	0.1289474	12.8947368	203	0.27202	0.00130187	417.8902
10	0.1315789	13.1578947	205	0.2747	0.00130582	420.7324
10.4	0.1368421	13.6842105	211	0.28274	0.00131378	430.422
10.6	0.1394737	13.9473684	213.5	0.28609	0.0013178	434.194
10.8	0.1421053	14.2105263	216	0.28944	0.00132184	437.9348
11	0.1447368	14.4736842	218	0.29212	0.00132591	440.634
11.2	0.1473684	14.7368421	220.5	0.29547	0.00133	444.3158
11.4	0.1500000	15	223	0.29882	0.00133412	447.9665
11.6	0.1526316	15.2631579	225	0.3015	0.00133826	450.5848
11.8	0.1552632	15.5263158	227	0.30418	0.00134243	453.1782
12	0.1578947	15.7894737	230.5	0.30887	0.00134663	458.732
12.2	0.1605263	16.0526316	233.5	0.31289	0.00135085	463.2503
12.4	0.1631579	16.3157895	236	0.31624	0.00135509	466.7424
12.6	0.1657895	16.5789474	238	0.31892	0.00135937	469.2177
12.8	0.1684211	16.8421053	241	0.32294	0.00136367	473.6333
13	0.1710526	17.1052632	243.5	0.32629	0.001368	477.0322
13.4	0.1763158	17.6315789	249	0.33366	0.00137674	484.7098
13.6	0.1789474	17.8947368	251	0.33634	0.00138115	487.042
13.8	0.1815789	18.1578947	253	0.33902	0.00138559	489.3494
14	0.1842105	18.4210526	255	0.3417	0.00139006	491.6319
14.2	0.1868421	18.6842105	257	0.34438	0.00139456	493.8894
14.4	0.1894737	18.9473684	258	0.34572	0.00139909	494.2066
14.6	0.1921053	19.2105263	259	0.34706	0.00140365	494.5114
14.8	0.1947368	19.4736842	260	0.3484	0.00140824	494.8037
15	0.1973684	19.7368421	261	0.34974	0.00141285	495.0835
15.4	0.2026316	20.2631579	261.5	0.35041	0.00142218	492.7793
15.6	0.2052632	20.5263158	261.5	0.35041	0.00142689	491.153
15.8	0.2078947	20.7894737	261	0.34974	0.00143163	488.5906
16	0.2105263	21.0526316	260	0.3484	0.0014364	485.1016
16.2	0.2131579	21.3157895	259	0.34706	0.0014412	481.6251
16.4	0.2157895	21.5789474	257	0.34438	0.00144604	476.3076

For Tony Soil Samples
weight of sample=164.5gm

Axial Deformation (mm)	Strain (Ɛ)	Axial Strain (%)	Proving Ring Rading (Div)	Axial Load (KN	Corrected Area (m2)	Axial Stress (Kpa)
0	0	0	0	0	0.001134	0
0.2	0.0026316	0.263158	21	0.02814	0.001137	35.75909
0.4	0.0052632	0.526316	44	0.05896	0.00114	74.72611
0.6	0.0078947	0.789474	54	0.07236	0.001143	91.4667
0.8	0.0105263	1.052632	63	0.08442	0.001146	106.4281
1	0.0131579	1.315789	70	0.0938	0.001149	117.9389
1.2	0.0157895	1.578947	77	0.10318	0.001152	129.3869
1.4	0.0184211	1.842105	84	0.11256	0.001155	140.7719
1.8	0.0236842	2.368421	85.5	0.11457	0.001162	142.5174
2	0.0263158	2.631579	94	0.12596	0.001165	156.2635
2.2	0.0289474	2.894737	98	0.13132	0.001168	162.4727
2.4	0.0315789	3.157895	102.5	0.13735	0.001171	169.4726
2.6	0.0342105	3.421053	106	0.14204	0.001174	174.7833
2.8	0.0368421	3.684211	110	0.1474	0.001177	180.8846
3	0.0394737	3.947368	112.5	0.15075	0.001181	184.4902
3.2	0.0421053	4.210526	115	0.1541	0.001184	188.0733
3.4	0.0447368	4.473684	117.5	0.15745	0.001187	191.6339
3.6	0.0473684	4.736842	120	0.1608	0.00119	195.1721
3.8	0.0500000	5	122.5	0.16415	0.001194	198.6878
4	0.0526316	5.263158	124	0.16616	0.001197	200.5636
4.2	0.0552632	5.526316	126	0.16884	0.0012	203.2324
4.4	0.0578947	5.789474	128	0.17152	0.001204	205.8832
4.6	0.0605263	6.052632	130	0.1742	0.001207	208.516
4.8	0.0631579	6.315789	132	0.17688	0.00121	211.1309
5	0.0657895	6.578947	133.5	0.17889	0.001214	212.9303
5.2	0.0684211	6.842105	135	0.1809	0.001217	214.7163
5.4	0.0710526	7.105263	136.5	0.18291	0.001221	216.4887
5.6	0.0736842	7.368421	138	0.18492	0.001224	218.2477
5.8	0.0763158	7.631579	139.5	0.18693	0.001228	219.9932
6	0.0789474	7.894737	141	0.18894	0.001231	221.7252
6.2	0.0815789	8.157895	142	0.19028	0.001235	222.6597
6.4	0.0842105	8.421053	143.5	0.19229	0.001238	224.367
6.6	0.0868421	8.684211	144.5	0.19363	0.001242	225.2813
6.8	0.0894737	8.947368	146	0.19564	0.001245	226.9639
7	0.0921053	9.210526	146.5	0.19631	0.001249	227.083

7.2	0.0947368	9.473684	147	0.19698	0.001253	227.1976
7.4	0.0973684	9.736842	148	0.19832	0.001256	228.0782
7.6	0.1000000	10	149	0.19966	0.00126	228.9498
7.8	0.1026316	10.26316	150	0.201	0.001264	229.8124
8	0.1052632	10.52632	150.5	0.20167	0.001267	229.9023
8.2	0.1078947	10.78947	151	0.20234	0.001271	229.9877
8.4	0.1105263	11.05263	152	0.20368	0.001275	230.8278
8.6	0.1131579	11.31579	152.5	0.20435	0.001279	230.902
8.8	0.1157895	11.57895	153	0.20502	0.001283	230.9716
9	0.1184211	11.84211	153.5	0.20569	0.001286	231.0368
9.2	0.1210526	12.10526	154.5	0.20703	0.00129	231.8477
9.4	0.1236842	12.36842	155	0.2077	0.001294	231.9016
9.6	0.1263158	12.63158	156	0.20904	0.001298	232.6969
9.8	0.1289474	12.89474	156.25	0.209375	0.001302	232.3678
10	0.1315789	13.15789	157	0.21038	0.001306	232.7778
10.2	0.1342105	13.42105	157.25	0.210715	0.00131	232.4419
10.4	0.1368421	13.68421	157.5	0.21105	0.001314	232.1038
10.6	0.1394737	13.94737	158	0.21172	0.001318	232.1308
10.8	0.1421053	14.21053	158.5	0.21239	0.001322	232.1533
11	0.1447368	14.47368	159.5	0.21373	0.001326	232.9013
11.2	0.1473684	14.73684	160	0.2144	0.00133	232.9126
11.4	0.1500000	15	160.5	0.21507	0.001334	232.9193
11.6	0.1526316	15.26316	161	0.21574	0.001338	232.9215
11.8	0.1552632	15.52632	161.75	0.216745	0.001342	233.2798
12	0.1578947	15.78947	162	0.21708	0.001347	232.9126
12.2	0.1605263	16.05263	162.5	0.21775	0.001351	232.9013
12.4	0.1631579	16.31579	162.75	0.218085	0.001355	232.5284
12.6	0.1657895	16.57895	163	0.21842	0.001359	232.1533
12.8	0.1684211	16.84211	163.5	0.21909	0.001364	232.1308
13	0.1710526	17.10526	164	0.21976	0.001368	232.1038
13.2	0.1736842	17.36842	164.25	0.220095	0.001372	231.7197
13.4	0.1763158	17.63158	164.5	0.22043	0.001377	231.3333
13.6	0.1789474	17.89474	164.75	0.220765	0.001381	230.9447
13.8	0.1815789	18.15789	165	0.2211	0.001386	230.5538
14	0.1842105	18.42105	165.25	0.221435	0.00139	230.1606
14.2	0.1868421	18.68421	165.5	0.22177	0.001395	229.7653
14.4	0.1894737	18.94737	165.75	0.222105	0.001399	229.3676
14.6	0.1921053	19.21053	166	0.22244	0.001404	228.9678
14.8	0.1947368	19.47368	166	0.22244	0.001408	228.222
15	0.1973684	19.73684	166	0.22244	0.001413	227.4761
15.4	0.2026316	20.26316	165.5	0.22177	0.001422	225.3038

15.6	0.2052632	20.52632	163.5	0.21909	0.001427	221.8465
15.8	0.2078947	20.78947	162	0.21708	0.001432	219.0834
16	0.2105263	21.05263	158.5	0.21239	0.001436	213.638
16.2	0.2131579	21.31579	155.75	0.208705	0.001441	209.2315
16.4	0.2157895	21.57895	153	0.20502	0.001446	204.8498

For Goro Site Soil Samples

Axial Deformation (mm)	Strain (Ɛ)	Axial Strain (%)	Proving Ring Rading (Div)	Axial Load (KN	Corrected Area (m2)	Axial Stress (Kpa)
0	0	0	0	0	0.001134	0
0.2	0.0026316	0.263158	20	0.0268	0.001137	28.28454
0.4	0.0052632	0.526316	39	0.05226	0.00114	55.00933
0.6	0.0078947	0.789474	50	0.067	0.001143	70.33821
0.8	0.0105263	1.052632	58	0.07772	0.001146	81.3759
1	0.0131579	1.315789	68	0.09112	0.001149	95.15249
1.2	0.0157895	1.578947	76	0.10184	0.001152	106.0633
1.4	0.0184211	1.842105	86	0.11524	0.001155	119.6981
1.6	0.0210526	2.105263	98	0.13132	0.001158	136.0345
1.8	0.0236842	2.368421	117	0.15678	0.001162	161.9719
2	0.0263158	2.631579	134	0.17956	0.001165	185.0063
2.2	0.0289474	2.894737	152	0.20368	0.001168	209.2907
2.4	0.0315789	3.157895	173	0.23182	0.001171	237.5603
2.6	0.0342105	3.421053	195	0.2613	0.001174	267.0427
2.8	0.0368421	3.684211	207	0.27738	0.001177	282.7036
3	0.0394737	3.947368	218	0.29212	0.001181	296.9131
3.2	0.0421053	4.210526	234	0.31356	0.001184	317.8317
3.4	0.0447368	4.473684	250	0.335	0.001187	338.6309
3.6	0.0473684	4.736842	265	0.3551	0.00119	357.9599
3.8	0.0500000	5	280	0.3752	0.001194	377.177
4	0.0526316	5.263158	293	0.39262	0.001197	393.5955
4.2	0.0552632	5.526316	304	0.40736	0.0012	407.2377
4.4	0.0578947	5.789474	315	0.4221	0.001204	420.7979
4.6	0.0605263	6.052632	326	0.43684	0.001207	434.276
4.8	0.0631579	6.315789	336	0.45024	0.00121	446.3435
5	0.0657895	6.578947	347	0.46498	0.001214	459.6612
5.2	0.0684211	6.842105	357	0.47838	0.001217	471.5757
5.4	0.0710526	7.105263	366	0.49044	0.001221	482.0985

5.6	0.0736842	7.368421	374	0.50116	0.001224	491.2406
5.8	0.0763158	7.631579	381.5	0.51121	0.001228	499.6681
6	0.0789474	7.894737	388	0.51992	0.001231	506.7337
6.2	0.0815789	8.157895	394	0.52796	0.001235	513.0995
6.4	0.0842105	8.421053	399	0.53466	0.001238	518.1221
6.6	0.0868421	8.684211	402	0.53868	0.001242	520.5177
6.8	0.0894737	8.947368	404	0.54136	0.001245	521.5998
7	0.0921053	9.210526	405	0.5427	0.001249	521.3797
7.2	0.0947368	9.473684	401	0.53734	0.001253	514.7339
7.4	0.0973684	9.736842	390	0.5226	0.001256	499.1588
7.6	0.1000000	10	383	0.51322	0.00126	488.7704
7.8	0.1026316	10.26316	369	0.49446	0.001264	469.5272
8	0.1052632	10.52632		0	0.001267	0

For Sabian Site Soil Samples
weight of sample=159.4gm

Axial Deformation (mm)	Strain (Ɛ)	Axial Strain (%)	Proving Ring Rading (Div)	Axial Load (KN	Corrected Area (m2)	Axial Stress (Kpa)
0	0	0	0	0	0.001134	0
0.2	0.002632	0.263158	13	0.01742	0.001137	20.16971
0.4	0.005263	0.526316	23	0.03082	0.00114	35.59072
0.6	0.007895	0.789474	46	0.06164	0.001143	70.99313
0.8	0.010526	1.052632	65	0.0871	0.001146	100.0503
1	0.013158	1.315789	82	0.10988	0.001149	125.8816
1.2	0.015789	1.578947	92	0.12328	0.001152	140.8564
1.4	0.018421	1.842105	118	0.15812	0.001155	180.1806
1.6	0.021053	2.105263	131	0.17554	0.001158	199.4947
1.8	0.023684	2.368421	142	0.19028	0.001162	215.6649
2	0.026316	2.631579	152	0.20368	0.001165	230.2303
2.2	0.028947	2.894737	161	0.21574	0.001168	243.2033
2.4	0.031579	3.157895	171	0.22914	0.001171	257.609
2.6	0.034211	3.421053	180	0.2412	0.001174	270.4305
2.8	0.036842	3.684211	187	0.25058	0.001177	280.1817
3	0.039474	3.947368	195	0.2613	0.001181	291.3699
3.2	0.042105	4.210526	201	0.26934	0.001184	299.5122
3.4	0.044737	4.473684	206	0.27604	0.001187	306.1195
3.6	0.047368	4.736842	211	0.28274	0.00119	312.6858
3.8	0.05	5	217	0.29078	0.001194	320.689
4	0.052632	5.263158	222	0.29748	0.001197	327.1693
4.2	0.055263	5.526316	226	0.30284	0.0012	332.1391

4.4	0.057895	5.789474	231	0.30954	0.001204	338.5417
4.6	0.060526	6.052632	236	0.31624	0.001207	344.9033
4.8	0.063158	6.315789	241	0.32294	0.00121	351.224
5	0.065789	6.578947	246	0.32964	0.001214	357.5037
5.2	0.068421	6.842105	249	0.33366	0.001217	360.8442
5.4	0.071053	7.105263	254	0.34036	0.001221	367.0503
5.6	0.073684	7.368421	259	0.34706	0.001224	373.2154
5.8	0.076316	7.631579	263	0.35242	0.001228	377.9027
6	0.078947	7.894737	267	0.35778	0.001231	382.5573
6.2	0.081579	8.157895	270	0.3618	0.001235	385.7503
6.4	0.084211	8.421053	273.5	0.36649	0.001238	389.6312
6.6	0.086842	8.684211	276	0.36984	0.001242	392.0628
6.8	0.089474	8.947368	279	0.37386	0.001245	395.1823
7	0.092105	9.210526	281	0.37654	0.001249	396.8648
7.2	0.094737	9.473684	284	0.38056	0.001253	399.9391
7.4	0.097368	9.736842	286.5	0.38391	0.001256	402.2869
7.6	0.1	10	288.5	0.38659	0.00126	403.9141
7.8	0.102632	10.26316	291	0.38994	0.001264	406.223
8	0.105263	10.52632	292	0.39128	0.001267	406.4236
8.2	0.107895	10.78947	294	0.39396	0.001271	408.0038
8.4	0.110526	11.05263	295.25	0.395635	0.001275	408.5298
8.6	0.113158	11.31579	296	0.39664	0.001279	408.3558
8.8	0.115789	11.57895	297	0.39798	0.001283	408.5196
9	0.118421	11.84211	299	0.40066	0.001286	410.0465
9.2	0.121053	12.10526	300	0.402	0.00129	410.1898
9.4	0.123684	12.36842	301.5	0.40401	0.001294	411.0065
9.6	0.126316	12.63158	302	0.40468	0.001298	410.4518
9.8	0.128947	12.89474	302.5	0.40535	0.001302	409.893
10	0.131579	13.15789	303	0.40602	0.001306	409.3301
10.2	0.134211	13.42105	304	0.40736	0.00131	409.4366
10.4	0.136842	13.68421	305	0.4087	0.001314	409.5348
10.6	0.139474	13.94737	305.5	0.40937	0.001318	408.9555
10.8	0.142105	14.21053	306	0.41004	0.001322	408.3722
11	0.144737	14.47368	306.5	0.41071	0.001326	407.7847
11.2	0.147368	14.73684	307	0.41138	0.00133	407.1932
11.4	0.15	15	307.25	0.411715	0.001334	406.267
11.6	0.152632	15.26316	307.5	0.41205	0.001338	405.3388
11.8	0.155263	15.52632	308	0.41272	0.001342	404.737
12	0.157895	15.78947	308.25	0.413055	0.001347	403.8036
12.2	0.160526	16.05263	308.5	0.41339	0.001351	402.8682
12.4	0.163158	16.31579	308.75	0.413725	0.001355	401.9307

12.6	0.165789	16.57895	309	0.41406	0.001359	400.9912
12.8	0.168421	16.84211	309	0.41406	0.001364	399.7263
13	0.171053	17.10526	309	0.41406	0.001368	398.4613
13.2	0.173684	17.36842	309	0.41406	0.001372	397.1964
13.4	0.176316	17.63158	309	0.41406	0.001377	395.9314
13.6	0.178947	17.89474	309	0.41406	0.001381	394.6664
13.8	0.181579	18.15789	309	0.41406	0.001386	393.4015
14	0.184211	18.42105	309	0.41406	0.00139	392.1365
14.2	0.186842	18.68421	308.5	0.41339	0.001395	390.2391
14.4	0.189474	18.94737	308.25	0.413055	0.001399	388.661
14.6	0.192105	19.21053	308	0.41272	0.001404	387.0849
14.8	0.194737	19.47368	307	0.41138	0.001408	384.5714
15	0.197368	19.73684	306	0.41004	0.001413	382.066
15.2	0.2	20	305	0.4087	0.001418	379.5688
15.4	0.202632	20.26316	304	0.40736	0.001422	377.0799
15.6	0.205263	20.52632	303	0.40602	0.001427	374.5991

Appendix F

Computations and equations for selected samples

<u>**For Index Analysis**</u>

For Liquid Limit Determination **For Plastic Limit Determination**

a) <u>**Malka Jabdu**</u>

Lab One Lab One

Wn (%) = ((m2-m3)/(m3-m1)) * 100 Wn (%) = ((m2-m3)/(m3-m1)) * 100

= ((21.74-17.70)/ (17.70-8.32) *100 = ((14.72-13.28)/ (13.28-8.22)) *100

=43.07 % =28.46%

Lab Two Lab Two

Wn (%) = ((m2-m3)/(m3-m1)) * 100 Wn (%) = ((m2-m3)/(m3-m1)) * 100 = ((21.18-17.27)/ (17.27-8.42)) *100 = ((14.07-12.76)/ (12.76-8.19)) *100

=44.18 % =28.66%

Lab Three

Wn (%) = ((m2-m3)/(m3-m1)) * 100 PL= (28.46+28.66)/2

= ((24.15-19.33)/ (19.23-8.33)) *100 =28.56%

=45.13%

b) **For Goro Samples**

For Liquid Limit Determination **For Plastic Limit Determination**

Lab One Lab One

Wn (%) = ((m2-m3)/(m3-m1)) * 100

= ((30.98-24.6)/ (24.26-8.37) *100

=42.29 %

Wn (%) = ((m2-m3)/(m3-m1)) * 100

= ((14.63-13.25)/ (13.25-8.29)) *100

=27.82%

Lab Two

Wn (%) = ((m2-m3)/(m3-m1)) * 100

= ((31.87-24.76)/ (27.76-8.39)) *100

=43.43 %

Lab Two

Wn (%) = ((m2-m3)/(m3-m1)) * 100

= ((13.92-12.73)/ (12.73-8.21)) *100

=26.39%

Lab Three

Wn (%) = ((m2-m3)/(m3-m1)) * 100

= ((32.12-25)/ (25-9.45)) *100

=45.78%

PL= (27.82+26.39)/2

=27.1%

c) Tony Site Samples

For Liquid Limit Determination

Lab One

Wn (%) = ((m2-m3)/(m3-m1)) * 100

= ((21.98-17.92)/ (17.92-8.32) *100

=42.29 %

For Plastic Limit Determination

Lab One

Wn (%) = ((m2-m3)/(m3-m1)) * 100

= ((14.31-12.88)/ (12.88-8.22)) *100

=30.68%

Lab Two

Wn (%) = ((m2-m3)/(m3-m1)) * 100

= ((22.56-18.21)/ (18.21-8.42)) *100

=44.43 %

Lab Two

Wn (%) = ((m2-m3)/(m3-m1)) * 100

= ((14.22-13.03)/ (13.03-8.19)) *100

=24.58%

Lab Three

Wn (%) = ((m2-m3)/(m3-m1)) * 100

= ((23.72-18.86)/ (18.86-8.33)) *100

=46.15%

PL= (30.68+24.58)/2

=27.63%

d) Tony Site Samples

For Liquid Limit Determination

Lab One

Wn (%) = ((m2-m3)/(m3-m1)) * 100

= ((22.11-17.91)/ (17.91-8.32) *100

=43.79 %

Lab Two

Wn (%) = ((m2-m3)/(m3-m1)) * 100

= ((22.97-18.49)/ (18.49-8.42)) *100

For Plastic Limit Determination

Lab One

Wn (%) = ((m2-m3)/(m3-m1)) * 100

= ((14.29-12.91)/ (12.91-8.22)) *100

=29.45%

Lab Two

Wn (%) = ((m2-m3)/(m3-m1)) * 100

= ((14.23-12.97)/ (12.97-8.19)) *100

=44.49% =26.36%

Lab Three

Wn (%) = ((m2-m3)/(m3-m1)) * 100 PL= (29.42+26.36)/2

= ((23.44-18.76)/ (18.76-8.33)) *100 =27.89%

=44.87%

Group Index Determintion

A. For Malka Jabdu Site Soil Samples

$$GI=(F-35)\,[0.2+0.005(LL-40)]+0.01(F-15)(PI-10)$$

Where

F= Percentage of passing #200 sieve.

LL=Liquid Limit read from graph.

PI= Plastic Index (LL-PL)

Therefore; From Computation F200=44.12, LL=44.1, PL=28.56, PI=15.54

$GI=3.62\approx 4$

Then, From AASHTO table the soil classified under= A-7.

But, A-7 group is subdivided into A-7-5 or A-7-6 depending on the plastic limit.

For P.L.<30, the classification is A-7-6; for P.L ≥30, it is A-7-5.

Hence, PL=28.56 the soil at Malka Jabdu classified under A-7-6(4)

B. For Bargale Site soil samples

GI=(F-35) [0.2+0.005(LL-40)]+0.01(F-15)(PI-10)

From Computation F200=45.31, LL=44.2, PL=28.30, PI=15.90

GI=4.06 ≈ 4

Then, From AASHTO table the soil classified under A-7-6(4)

C. For Goro Site Soil Samples

GI=(F-35) [0.2+0.005(LL-40)]+0.01(F-15)(PI-10)

Accordingly, F200=39.34, LL=43.9, PL=27.1, PI=16.8

GI=2.58 ≈ 3

By AASHTO table the soil classified under A-7-6(3),

Computation for all samples continued in the same way!

For Unconfined Copmression strength tests

Strain $\varepsilon = \Delta L/L$ (%)

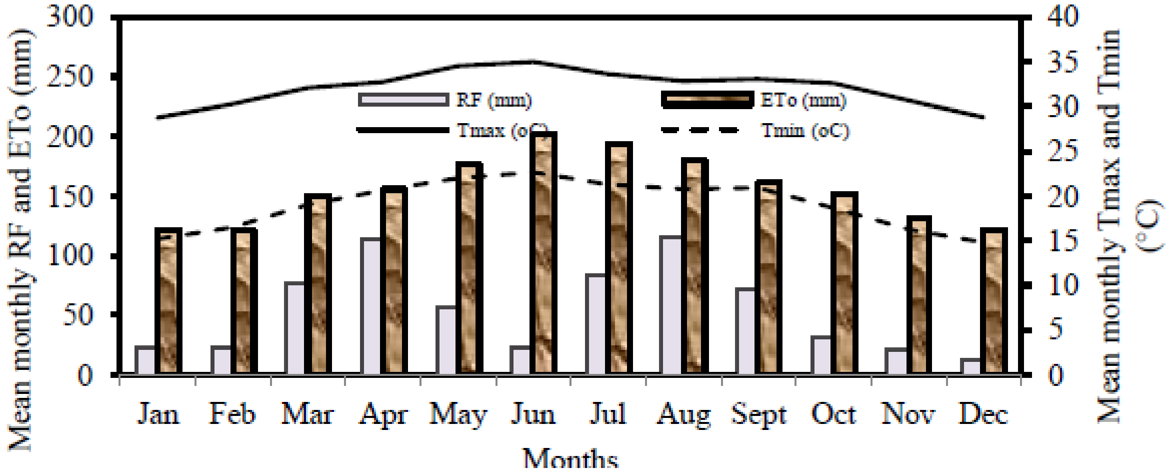
Area Corrected $A_c = A_o/(1-\varepsilon)$ (cm^2)

Compressive stress= P/Ac (Kg/cm^2)

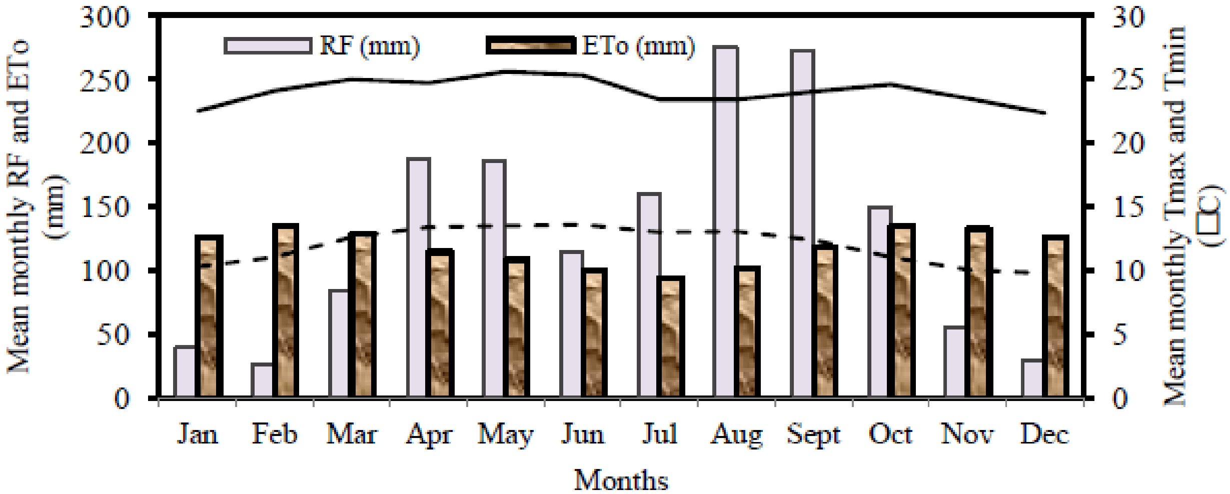
For P is axial load, ΔL is change in length of the samples under loading, L orginal length of the samples which is equal to 76cm. By having this formula and reading from machine the computation will continue.

Appendix G

Rain Fall Data



(a)



(b)

Mean monthly rainfall, maximum, and minimum temperatures of the Administration as recorded from (a) Dire Dawa Airport, and (b) Dhengego meteorological stations.